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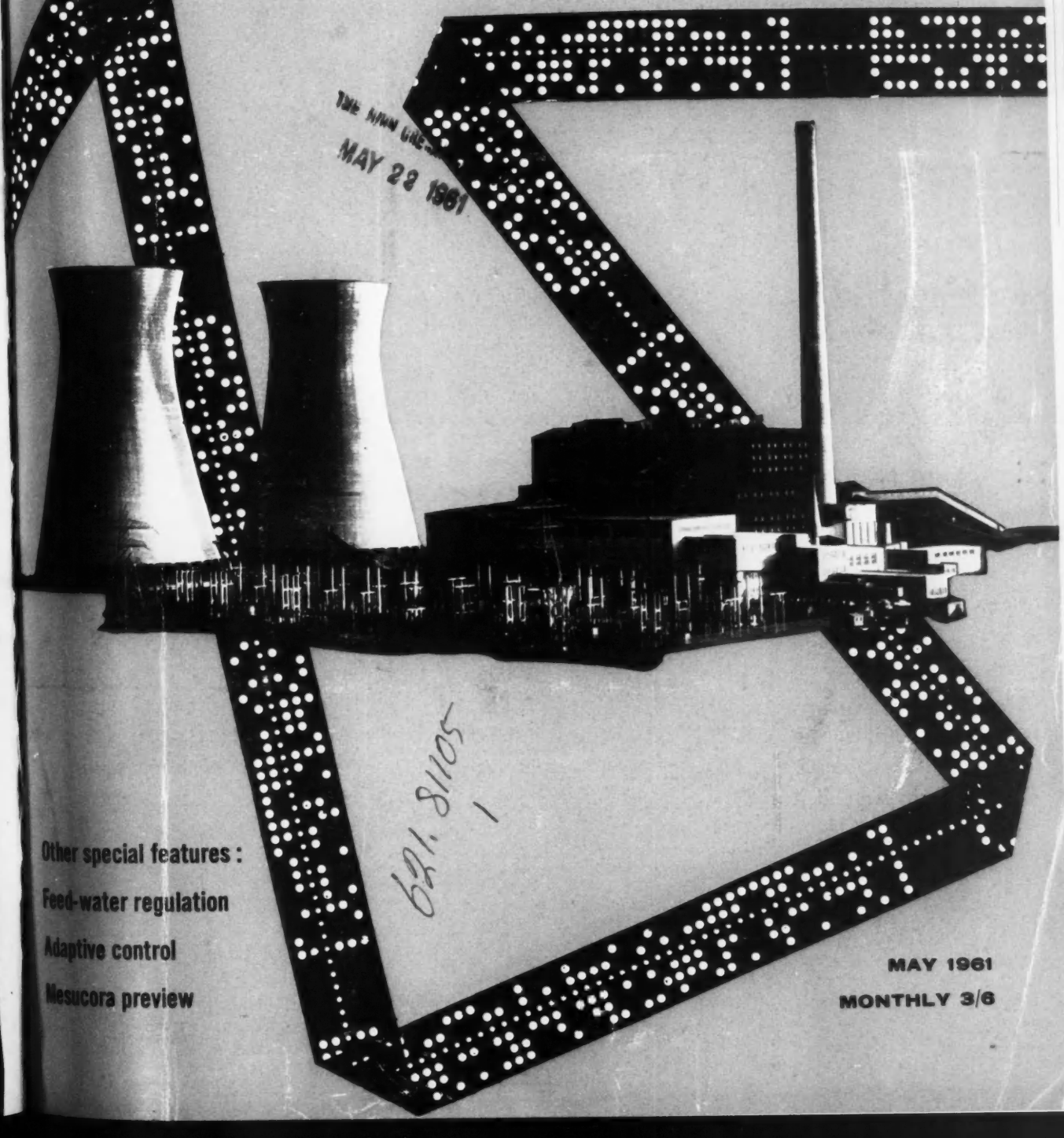
YSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

X-1

Computer in the power station, p. 84



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Adaptive control

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MAY 1961

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VOL 4 NO 35 MAY 1961

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CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

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LOOKING FOR A JOB? Control *carries the best jobs in instrument and control engineering.* **SEE PAGE 190 AND ONWARDS**

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RM ROWSE MUIR PUBLICATIONS LIMITED, LONDON, ENGLAND

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.A.C., British Conference on Automation and Computation. B.C.S., British Computer Society. Brit.I.R.E., British Institution of Radio Engineers. I.C.E., Institution of Civil Engineers. I.Chem.E., Institution of Chemical Engineers. I.E.E., Institution of Electrical Engineers. I.Mech.E., Institution of Mechanical Engineers. I.Prod.E., Institution of Production Engineers. I.S.A., Instrument Society of America. R.Ae.S., Royal Aeronautical Society. S.B.A.C., Society of British Aircraft Constructors. S.I.T., Society of Instrument Technology.

WEDNESDAY 3—SATURDAY 13 MAY
British Columbia International Trade Fair, Exhibition Park, Vancouver, Canada.

MONDAY 8—WEDNESDAY 10 MAY
4th National I.S.A. Power Instrumentation Symposium. La Salle Hotel, Chicago, Ill., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

TUESDAY 9—WEDNESDAY 10 MAY
Standards Engineers Conference. Details: B.S.I., 2 Park St, W.1.

TUESDAY 9—WEDNESDAY 17 MAY
International Exhibition of Measurement, Control, Regulation and Automation (Mesucora) and 58th Exhibition of French Physical Society. C.N.I.T., Paris. Secrétariat Général, 40, rue du Colisée, Paris, 8e, France.

WEDNESDAY 10—FRIDAY 12 MAY
Pulp and Paper Instrumentation Symposium. Northland Hotel, Green Bay, Wisc., U.S.A. Sponsors: I.S.A. and T.A.P.P.I. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

An international conference on *Materials handling*. Southport. Details: Institute of Materials Handling, 69 Cannon St, London, E.C.4.

THURSDAY 18—FRIDAY 19 MAY
Two-day course on *The future of the Seven*. Details: Federal Trust for Education and Research, 10 Wyndham Place, W.1.

FRIDAY 19 MAY—SUNDAY 4 JUNE
British Trade Fair, Moscow. Details: Industrial and Trade Fairs Ltd, Drury House, Russell St, Drury Lane, London, W.C.2.

MONDAY 22—WEDNESDAY 24 MAY
10th National Telemetering Conference, Hotel Morrison, Chicago, Ill., U.S.A., Sponsors: I.S.A., A.I.E.E., A.R.S., I.A.S., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

WEDNESDAY 24 MAY—SUNDAY 4 JUNE
The 24th Salon International de L'Aéronautique, Le Bourget, Paris, France.

MONDAY 29 MAY—SATURDAY 3 JUNE
the Industrial Equipment and Service Exhibition, Bingley Hall, Birmingham. Details: Lawson Trout Publicity Ltd, Temple Courts, 55 Temple Row, Birmingham 2.

TUESDAY 30 MAY—FRIDAY 2 JUNE
Radio and Electronic Component Show, Olympia. Details: Industrial Exhibitions Ltd, 9 Argyll St, W.1.

TUESDAY 6—THURSDAY 8 JUNE
I.S.A. Summer Instrument-Automation Conference and Exhibition, Royal York Hotel and Queen Elizabeth Hall, Toronto, Ont., Canada. Details: Wm H. Kushnick, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

FRIDAY 9—SATURDAY 17 JUNE
13th Chemical Engineering Exhibition and Congress, Frankfurt am Main. Details: Dechema, Decheme-Haus, Rheingau-Allee 25, Frankfurt am Main, Germany.

MONDAY 12 JUNE
Air Pollution Instrumentation Symposium (with the June 12–16 annual meeting of the Air Pollution Control Association), Hotel Commodore, New York City, N.Y., U.S.A. Sponsors: I.S.A. and A.P.C.A. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

MONDAY 12—THURSDAY 15 JUNE
British Electrical Power Convention: *Electricity in the prosperity and welfare of the nation*. Details: Electrical Development Association, 2 Savoy Hill, W.C.2.

MONDAY 12—SATURDAY 17 JUNE
Conference on *Components and materials used in electronic engineering*. Central Hall, Westminster, S.W.1. (*I.E.E.*)

TUESDAY 13—FRIDAY 16 JUNE
3rd Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

THURSDAY 15—FRIDAY 16 JUNE
Two open days at Bisra's Sheffield Laboratories. Details: D. U. Hunt, B.I.S.R.A., 11 Park Lane, London, W.1.

MONDAY 19—FRIDAY 23 JUNE
6th International Instrument Show, 4 Tilney St, Park Lane, W.1. Sponsors: B. & K. Laboratories.

WEDNESDAY 20—THURSDAY 28 JUNE
Third Congress of the European Federation of Chemical Engineering, Olympia. Details: The General Secretary, Society of Chemical Industry, 14 Belgrave Square, S.W.1.

MONDAY 26 JUNE—SATURDAY 1 JULY
International Measurements Conference, (Imeko), Budapest. Details: J. F. Coales, Cambridge University, Trumpington St, Cambridge, or Imeko Secretariat, Budapest 5, P.O.B. 3, Hungary.

TUESDAY 27—FRIDAY 30 JUNE
A conference on *The social and economic effects of automation*, sponsored by members of the B.C.A.C. Applications for tickets to The British Institute of Management, 80 Fetter Lane, E.C.4.

WEDNESDAY 28—FRIDAY 30 JUNE
2nd Joint Automatic Control Conference. University of Colorado, Boulder, Colo., U.S.A. Sponsors: I.S.A., A.I.Ch.E., A.I.E.E., A.S.M.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

WEDNESDAY 5—SATURDAY 9 JULY
Radio techniques and space research. A convention at Oxford University. (*Brit. I.R.E.*)

FRIDAY 7—SATURDAY 29 JULY
Russian Trade Fair, Earls Court. Details: Industrial and Trade Fairs Ltd, Drury House, Russell St, Drury Lane, W.C.2.

SUNDAY 16—FRIDAY 21 JULY
4th International Conference on *Medical electronics* at the Waldorf-Astoria, New York. Sponsors: I.R.E., A.I.E.E., I.S.A. Details: Institute of Radio Engineers, 1 East 79th St, New York City, N.Y., U.S.A.

LOOKING FURTHER AHEAD

TUESDAY 1—SATURDAY 12 AUGUST
Sydney Trade Fair, Sydney, N.S.W., Australia. Details: Press Office, Commonwealth House, Oxford St, London, W.C.1.

WED. 30 AUGUST—WED. 6 SEPTEMBER
Annual Meeting, British Association for the Advancement of Science, Norwich. Details: Secretary, B.A.A.S., 19 Adam St, Strand, London, W.C.2.

MONDAY 4—SATURDAY 9 SEPTEMBER
3rd International Session of the International Association for Analogue Computation. Belgrade, Yugoslavia. Details: Yugoslav Committee for Etan, Terazije, 23/VII, Belgrade, Yugoslavia.

MONDAY 4—SUNDAY 10 SEPTEMBER
S.B.A.C. Flying display and exhibition, Farnborough. Details: S.B.A.C., 29 King St, St James's, London, S.W.1.

TUESDAY 5—FRIDAY 8 SEPTEMBER
An international conference on *Machine translation of language and applied language analysis*. National Physical Laboratory, Teddington, Middlesex. Papers to Dr A. M. Uttley, Autonomics Division, N.P.L.

WEDNESDAY 6—FRIDAY 8 SEPTEMBER
International Symposium on *Transmission and processing of information*. Massachusetts Institute of Technology. Submission of papers is invited. Details: R. M. Fano, R.L.E., M.I.T., Cambridge, 39, Mass., U.S.A.

Joint Nuclear Instrumentation Symposium. North Carolina State College, Raleigh, N.C., U.S.A. Sponsors: I.S.A., A.I.E.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

MONDAY 11 SEPTEMBER
20th International Congress of Navigation. Baltimore. Details: Permanent International Association of Navigation Congresses, 60 rue Juste Lipse, Brussels, Belgium.

MONDAY 11—FRIDAY 15 SEPTEMBER
I.S.A. Instrument-Automation Conference and Exhibition and I.S.A.'s 16th Annual Meeting. Memorial Sports Arena, Los Angeles, Calif., U.S.A. Details: Wm H. Kushnick, I.S.A., 313 Sixth Av., Pittsburgh, 22, Pa, U.S.A.

MONDAY 18—FRIDAY 22 SEPTEMBER
Symposium on *Network theory*, Cranfield. Details: S.R. Deards, Department of Electrical and Control Engineering, The College of Aeronautics, Cranfield, Bletchley, Bucks.

TUESDAY 26 SEPTEMBER—FRIDAY 6 OCTOBER
International Heating, Ventilating and Air-conditioning Exhibition, Olympia. (A conference will run concurrently from Wednesday 27 September — Wednesday 4 October.) Sponsors: Institution of Heating and Ventilating Engineers.

WEDNESDAY 4—THURSDAY 12 OCTOBER
Second Electronic Computer Exhibition and Symposium, London. Details: Mrs S. S. Elliott, 64 Cannon St, E.C.4.

THURSDAY 5—FRIDAY 6 OCTOBER
Two-day export conference. Details: C. G. E. Parrot, Overseas Divn, B.E.A.M.A., 36 Kingsway, W.C.2.

THURSDAY 19 OCTOBER
The Thomson Lecture. An annual lecture on a general subject has been inaugurated by the S.I.T. The first, at 6 p.m. at the Royal Institution, is to be given by Sir George Thomson after whom the series is named. (*S.I.T.*)

WEDNESDAY 8—FRIDAY 10 NOVEMBER
Conference on *Non-destructive testing in electrical engineering*. (*I.E.E.*)

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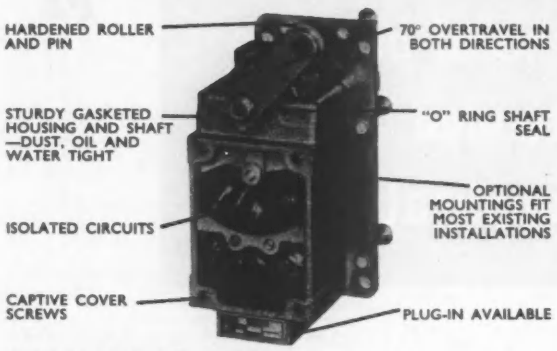
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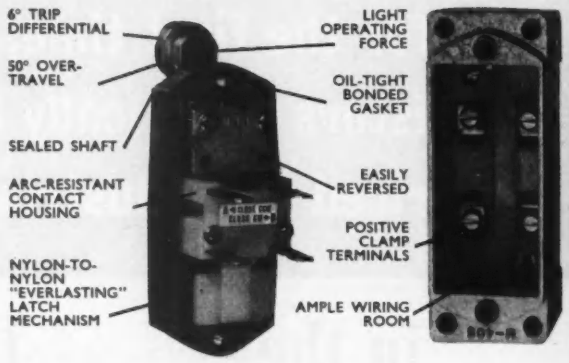

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250	15	1.5	30
500	7.5		15
600	6	.4	12

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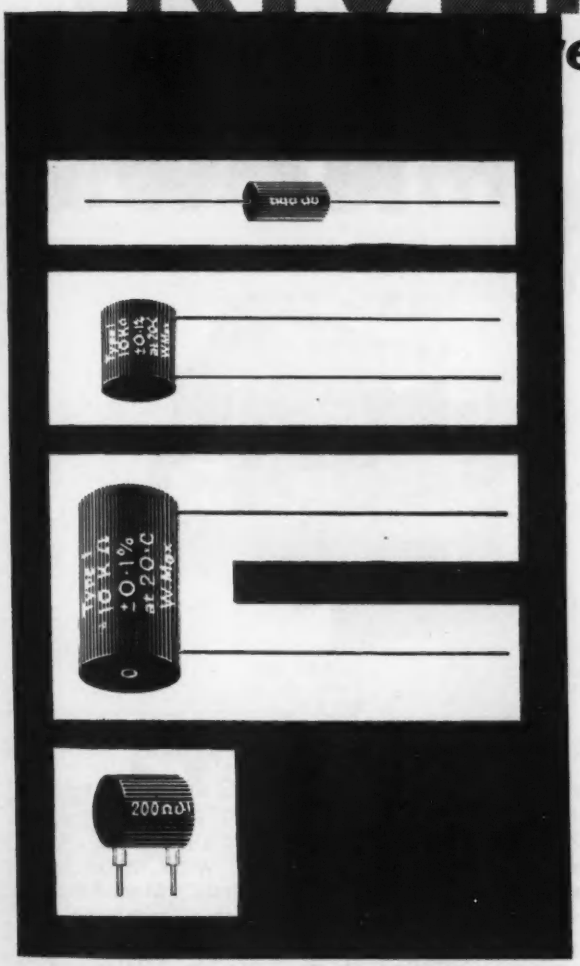

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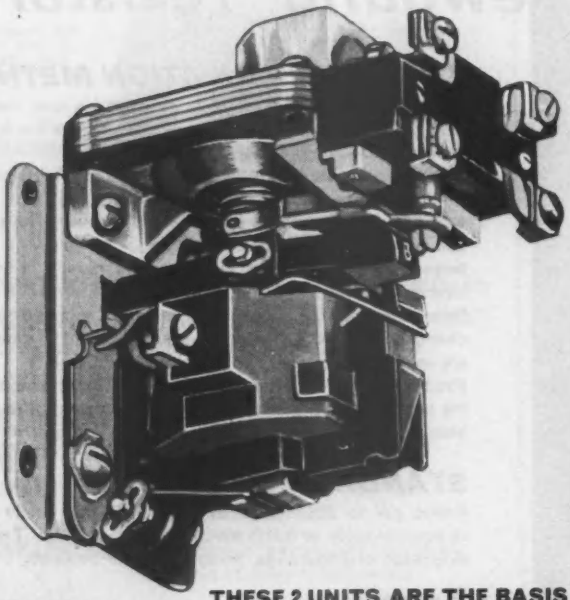

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TYPE AO-1E
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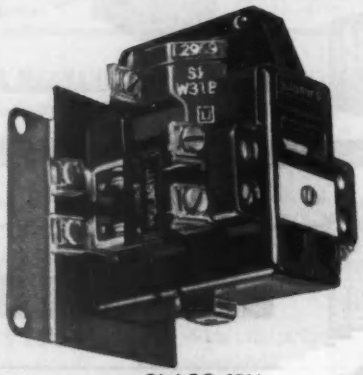

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TYPE DO-22
RELAY

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Complete selection . Relays available for both AC and DC systems—with up to 10 contacts—in both electrically and mechanically held forms. Timing relays with intervals from 0.2 seconds to 3.0 minutes—also in AC and DC versions. Require less panel space . Relays are only 3" wide range in height from 3¼" to 5". Timers are just 2⅝" x 4 3/16" or 2½" x 7 21/32". Mechanically held relays require no extra panel space. No mounting problems . All Type D relays and Type A timers have identical mounting hole dimensions. Easy wiring . Pressure wire connectors. Long life . Balanced construction with single moving parts increases life. Epoxy-resin moulded coil operates cooler, virtually eliminates coil burnout.

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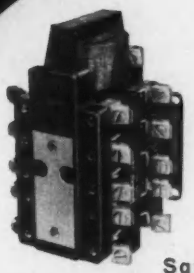
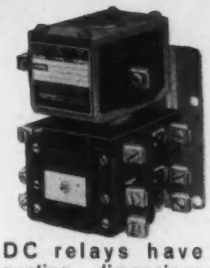
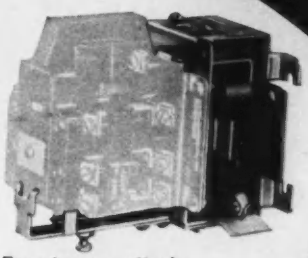


Square D Type D A.C. relays available with up to 10 contacts



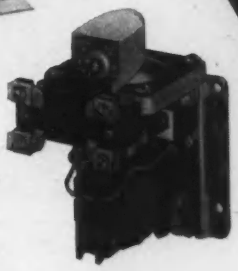
DC relays have mounting dimensions and contact arrangements identical to AC relays



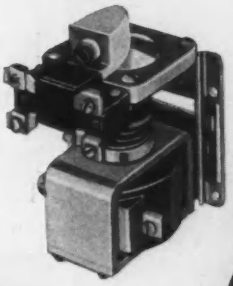
Easy-to-use attachment converts any Type D relay to mechanically held with no increase in panel space

NEW timer

A FURTHER ADDITION TO THE SQUARE D RELAY FAMILY

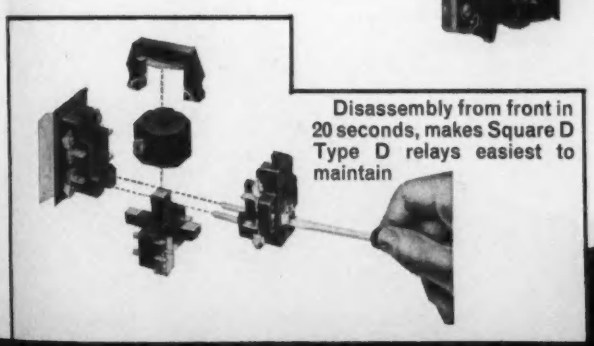


Timing relays have same mounting dimensions as Type D relays



Matching DC timing relays

Both AC and DC versions convertible from on-delay to off-delay, using only a screwdriver



Disassembly from front in 20 seconds, makes Square D Type D relays easiest to maintain

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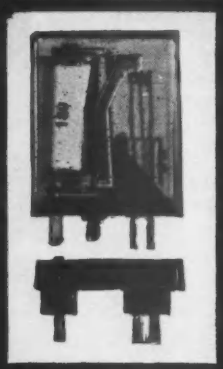
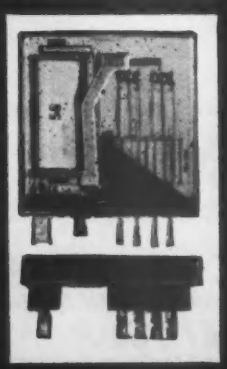


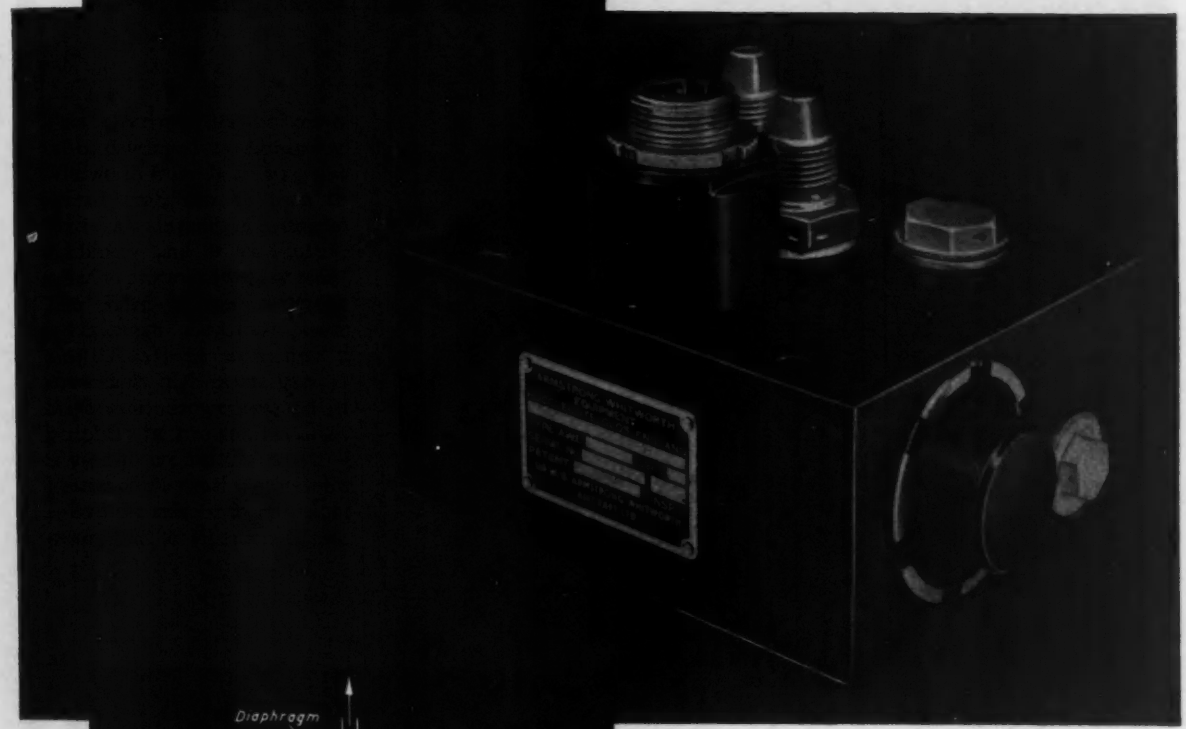
VP 2

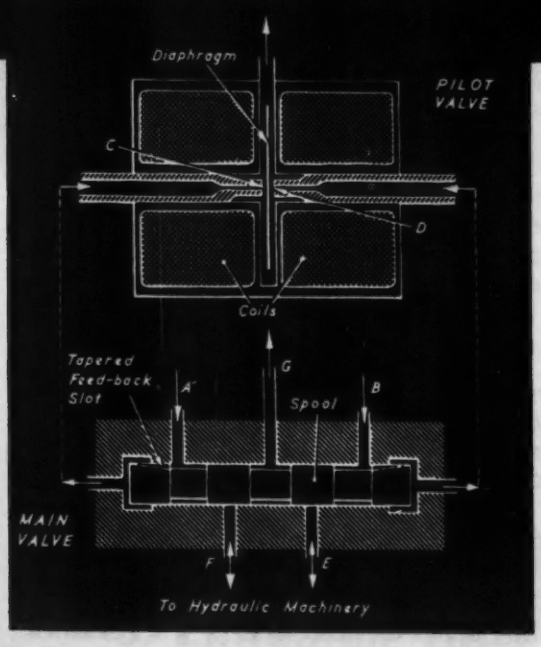


VP 4

* Type V.P.2. 0.75″×0.96″ Panel height 1.175″ (with socket 1.35″)
* Type V.P.4. 0.75″×1.18″ Panel height 1.175″ (with socket 1.35″)
* 2 or 4 pole changeover (other contact arrangements being developed)
* Operating voltages: 6-138v D.C.
* Operating times: 3½ to 7½ milliseconds
* Operating life: in excess of 10^7 operations.
* Contact ratings: 1 amp at 100v. Maximum watts: 30.
* Contact material: fine silver and gold alloy. Other contact materials will be available later.
* Plug-in and fitted with dust cover (Printed circuit socket later).

TYPE A·W·E 144/5 ELECTRO-HYDRAULIC SERVO VALVE





The valve — see diagram — consists of a main valve and a pilot valve. The main valve is supplied with pressure oil through ports A and B. When the spool is in the central position — as shown — the oil escapes through the tapered slots to the opposed jets C and D in the pilot valve and impinges on each side of the diaphragm. The two coils can be energised to attract the diaphragm towards one or other of the jets. If the signal to the right hand coil is the stronger, the diaphragm will flex to the right, restricting the flow from the right hand jet and thus increasing the pressure in that line. Similarly, the pressure in the left hand line is reduced. This pressure difference is transmitted to the main valve and causes the spool to move to the left until the resultant decrease in discharge area of the tapered slot at the right hand end of the spool and the increase in that at the left cause equilibrium to be restored. The displacement of the spool uncovers ports E and F, thus opening pressure and return lines to the hydraulic machinery.

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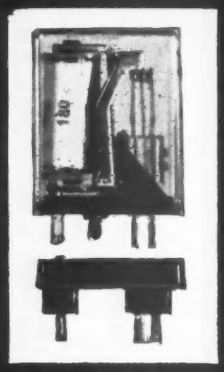
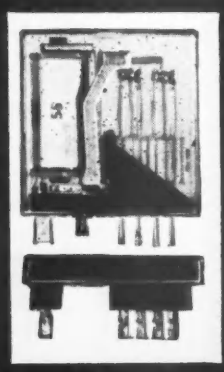
VP 2



VP 4



* Type V.P.2. 0.75″ × 0.96″ Panel height 1.175″ (with socket 1.35″)
* Type V.P.4. 0.75″ × 1.18″ Panel height 1.175″ (with socket 1.35″)
* 2 or 4 pole changeover (other contact arrangements being developed)
* Operating voltages: 6-138v D.C.
* Operating times: 3½ to 7½ milliseconds
* Operating life: in excess of 10^7 operations.
* Contact ratings: 1 amp at 100v. Maximum watts: 30.
* Contact material: fine silver and gold alloy. Other contact materials will be available later.
* Plug-in and fitted with dust cover (Printed circuit socket later).

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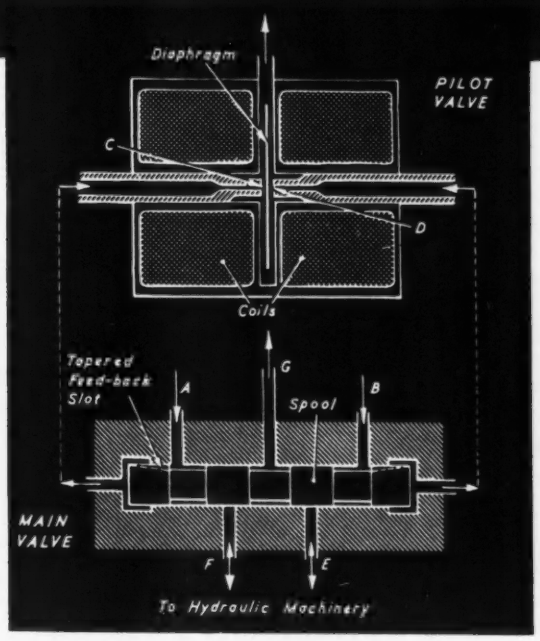
TYPE A·W·E 144/5 ELECTRO-HYDRAULIC SERVO VALVE



The valve — see diagram — consists of a main valve and a pilot valve. The main valve is supplied with pressure oil through ports A and B. When the spool is in the central position — as shown — the oil escapes through the tapered slots to the opposed jets C and D in the pilot valve and impinges on each side of the diaphragm. The two coils can be energised to attract the diaphragm towards one or other of the jets. If the signal to the right hand coil is the stronger, the diaphragm will flex to the right, restricting the flow from the right hand jet and thus increasing the pressure in that line. Similarly, the pressure in the left hand line is reduced. This pressure difference is transmitted to the main valve and causes the spool to move to the left until the resultant decrease in discharge area of the tapered slot at the right hand end of the spool and the increase in that at the left cause equilibrium to be restored. The displacement of the spool uncovers ports E and F, thus opening pressure and return lines to the hydraulic machinery.

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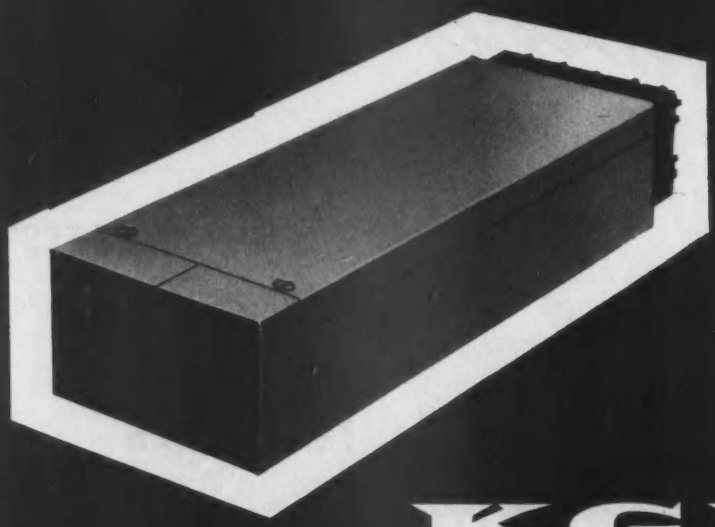
K.G.M. MULTI-INDICATOR M13



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Joint - Service/Inter - Service type approved lamps. Different colour displays are available.

Dimensions:

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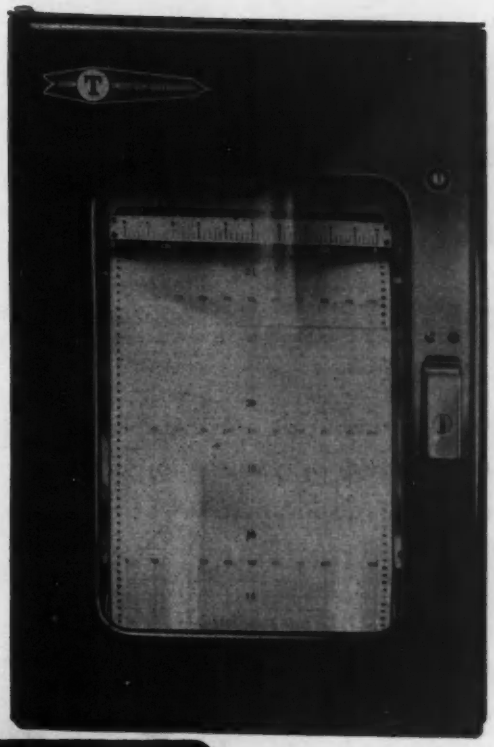
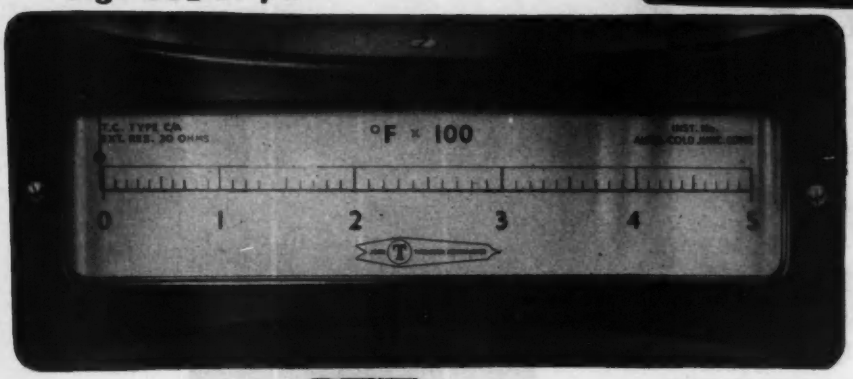
Measuring and recording temperature

and other conditions
e.g. CO_2 or *p*H





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Multipoint Recorder—6 in. chart
A compact and versatile addition to the Sentinel range; can indicate and record up to six different temperature (or other) conditions on a chart with each reading identified by colour and number. Twelve hours recording is always visible. Can be supplied as a controller or for alarm setting.

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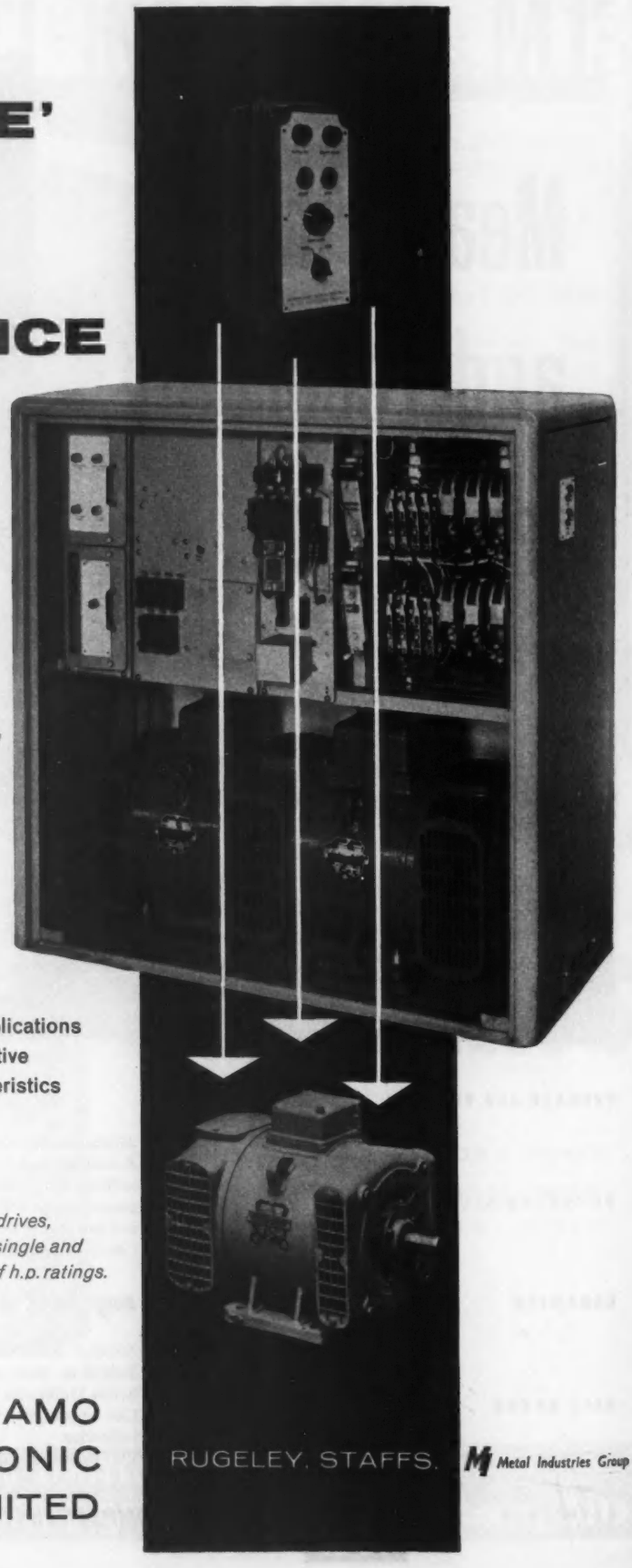
'TRANSIDYNE' MEANS PACKAGED PERFORMANCE

Precise transistor control of motor speed with this easily installed Transidyne controller



In ratings from 1 to 10 h.p., this range of highly rationalised drives is available with a wide variety of optional features, including reversal, dynamic braking, inching, tachogenerator control and a range of motor base-speeds, enclosures and mountings. A remote mounting control station provides pushbutton starting, reversing and fingertip speed setting.

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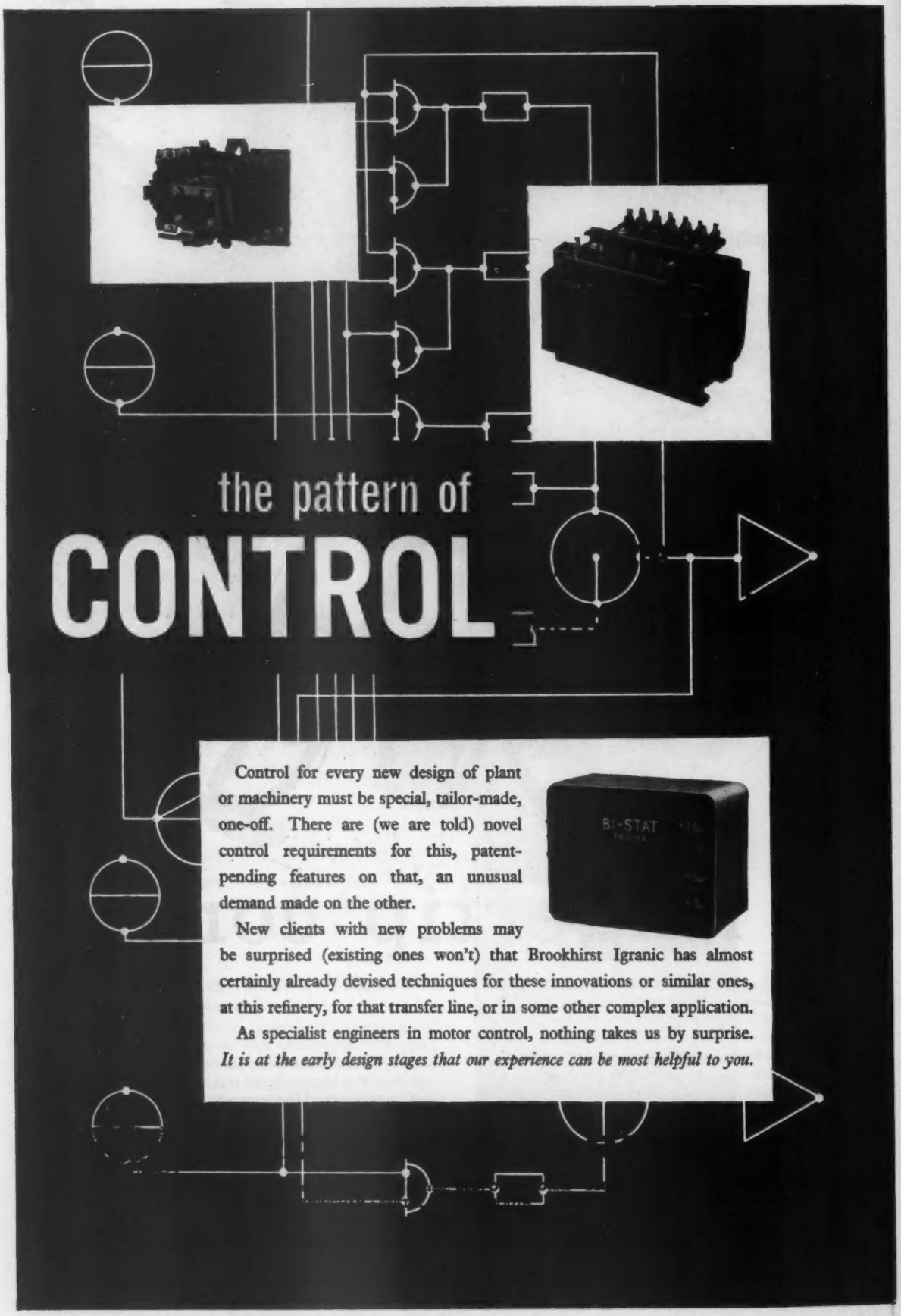
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CONTROL
Control for every new design of plant or machinery must be special, tailor-made, one-off. There are (we are told) novel control requirements for this, patent-pending features on that, an unusual demand made on the other.
New clients with new problems may be surprised (existing ones won't) that Brookhirst Igranic has almost certainly already devised techniques for these innovations or similar ones, at this refinery, for that transfer line, or in some other complex application.
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It is at the early design stages that our experience can be most helpful to you.

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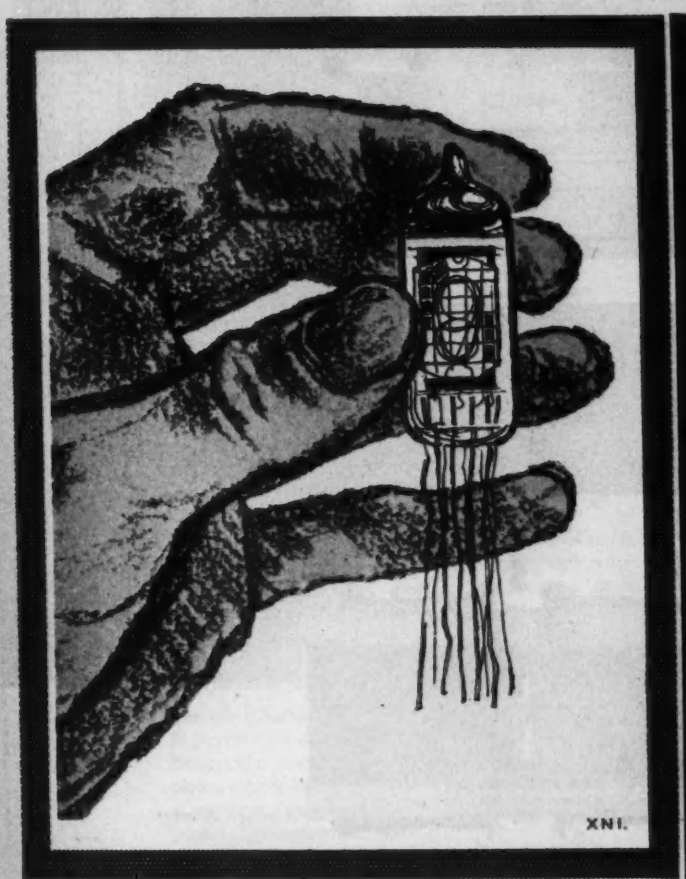

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* All digits appear *in the same position*, as seen from the front. Numicators accordingly offer the very great advantage of in-line display.

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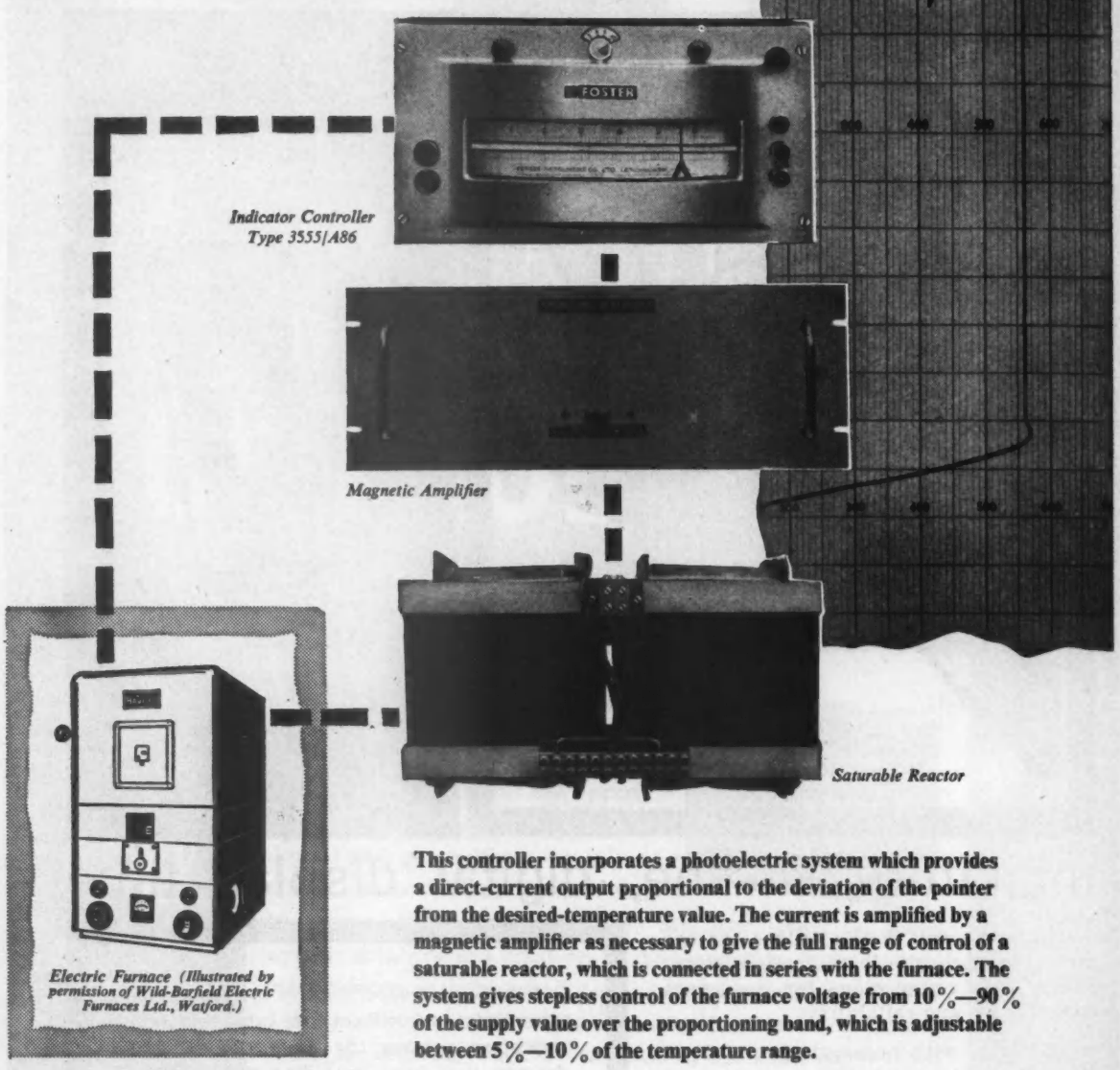
Saturable Reactor Control of Electric Furnace Temperature

(3555/A86 Indicating Temperature Controller)



Indicator Controller Type 3555/A86

Magnetic Amplifier

Saturable Reactor

Electric Furnace (Illustrated by permission of Wild-Barfield Electric Furnaces Ltd., Watford.)

This controller incorporates a photoelectric system which provides a direct-current output proportional to the deviation of the pointer from the desired-temperature value. The current is amplified by a magnetic amplifier as necessary to give the full range of control of a saturable reactor, which is connected in series with the furnace. The system gives stepless control of the furnace voltage from 10%—90% of the supply value over the proportioning band, which is adjustable between 5%—10% of the temperature range.

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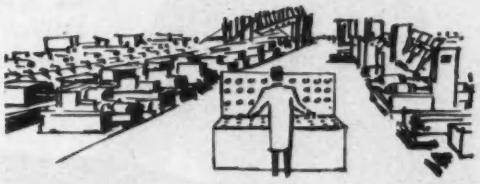
Electrical Aids in Industry — *Data Sheet* **No. 15**

Electric Motors & Controls-2

Control equipment must enable the motor to be operated effectively, to obtain maximum productive efficiency of a given machine. An outstanding advantage of individual electric drives is the flexibility of control available. Control equipment may be manual, semi-automatic or fully automatic, and includes gear for the following operations:

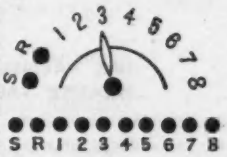
(a) Starting
(b) Speed Control (this subject will be dealt with in Data Sheet No. 16)
(c) Reversing
(d) Stopping
(e) Switching off automatically if operating conditions become abnormal
(f) Isolation of motor and control equipment from the supply.



Every application of power has its own particular control requirements—and they are legion. Below are featured four uses of electric motors and their controls; they are given only as examples and represent but a small fraction of the whole picture.

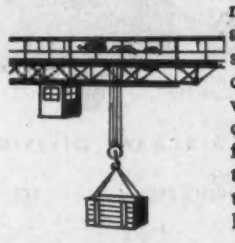
Turret-lathe Control

Various speeds are required for different tools, and it is possible to arrange, for instance, for a four-speed headstock, forward and reverse, incorporating a power-operated pre-selector speed change. By using a two-speed double-wound motor, eight speeds forward or reverse are obtainable. A dial on the headstock is set to the required speed and when a knob in the centre of the dial is pressed, the power-operated mechanism changes the speed instantly.



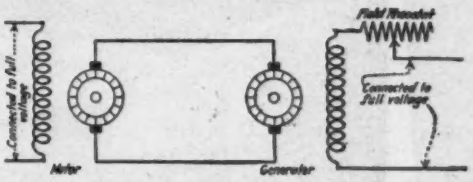
Crane Control

This is a form of control which must be flexible yet completely foolproof. It is, for instance, possible to arrange for motor switching to be performed by contactors in response to movement of the crane driver's master controller which has a number of notches, each of which is associated with a particular set of contactors for acceleration, speed control, reversing and braking. If the controller is moved quickly from the 'off' position to the 'last point lowering', the rate of acceleration is limited automatically by the relays. These also govern the retardation in order to prevent a heavy descending load being stopped too suddenly. This is just one of the ways in which electric control mitigates the hazards of crane operation.



Planing-machine Control

Another example of motor control for machine tools is that for planing machines. For general workshop machining, the Ward-Leonard controlled motor, with a speed range of 10 to 1, gives a rapid and smooth reversal of the table travel and is ideally suited for short-stroke work. Two arrangements of Ward-Leonard control are available, the 3-machine set with generator, exciter and driving motor, and a specially designed 4-machine set with an additional auxiliary exciter. With the 3-machine set the control



equipment can include magnetic time relays which automatically adjust a regulator to strengthen the motor field at the instant of reversal and therefore greatly increase the accelerating torque. The auxiliary exciter of the 4-machine set automatically provides 'field forcing' on the generator; in other words, the power input to the motor is increased to give more accelerating torque at the instant of reversal.

Automatic Control

The control equipments described incorporate automatic features which help considerably towards obtaining safe and efficient operation of the driven machine, but much still depends on the human element. Braking equipment, for instance, cannot always become effective until an operative has taken some action. In an emergency this physiological time lag which delays the initial action will also delay the final effect. Fortunately it is often practicable to employ devices, which will be described in other Data Sheets, to 'observe' any abnormal condition and immediately and automatically to initiate the braking system.

Particular attention should be paid to the positioning of controls. When a machine, or group of machines, requires a large number of push buttons and, in some cases, instruments, etc., the controls can be grouped on a desk with a mimic diagram, located in a position where the operator has full view of the work.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. TEMple Bar 9434.

They can offer you excellent reference books on electricity and productivity (8/6, or 9/- post free)—'Electric Motors and Controls' is an example.

E.D.A. also have available on free loan within the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

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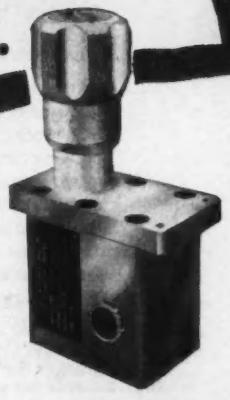
HML CAN MEET YOUR REQUIREMENTS FOR HYDRAULIC TESTS ...



HML VARIABLE PRESSURE REDUCER VALVE

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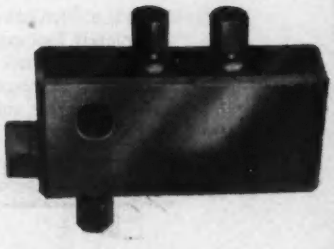

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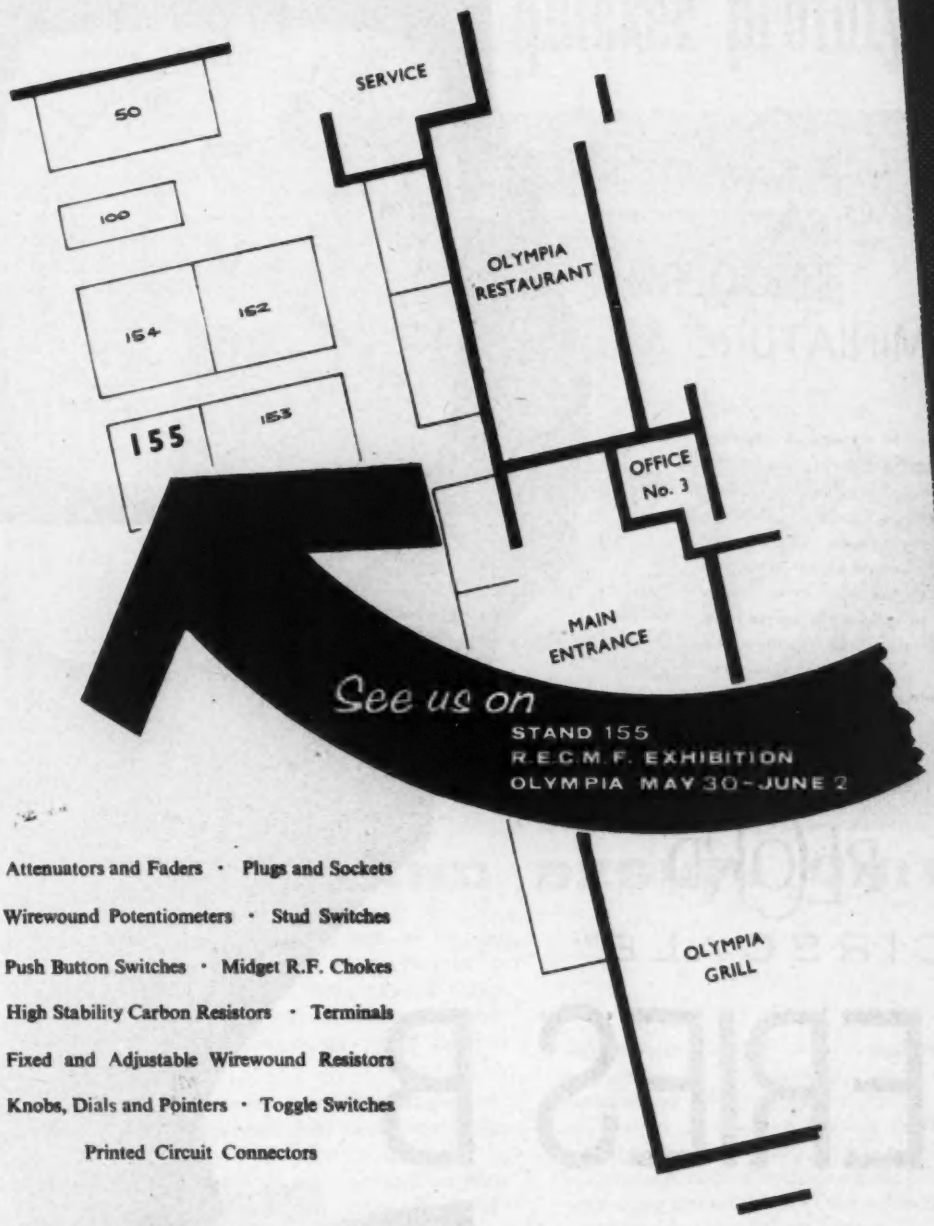

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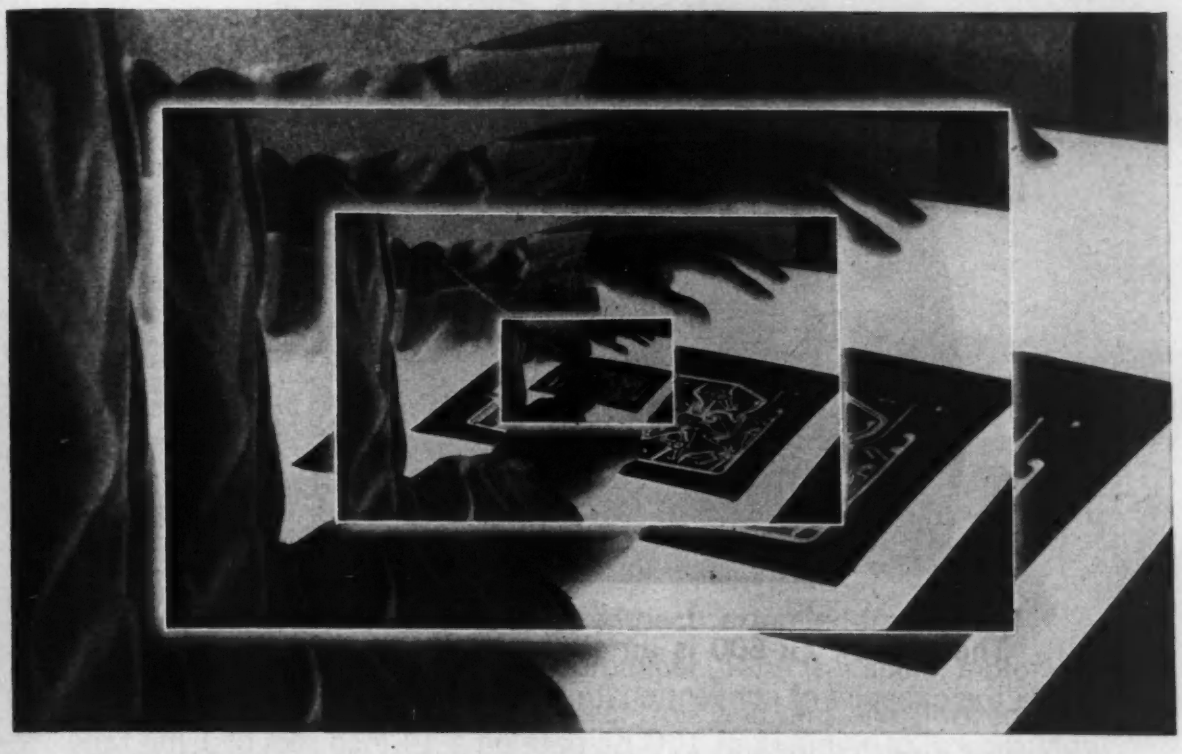

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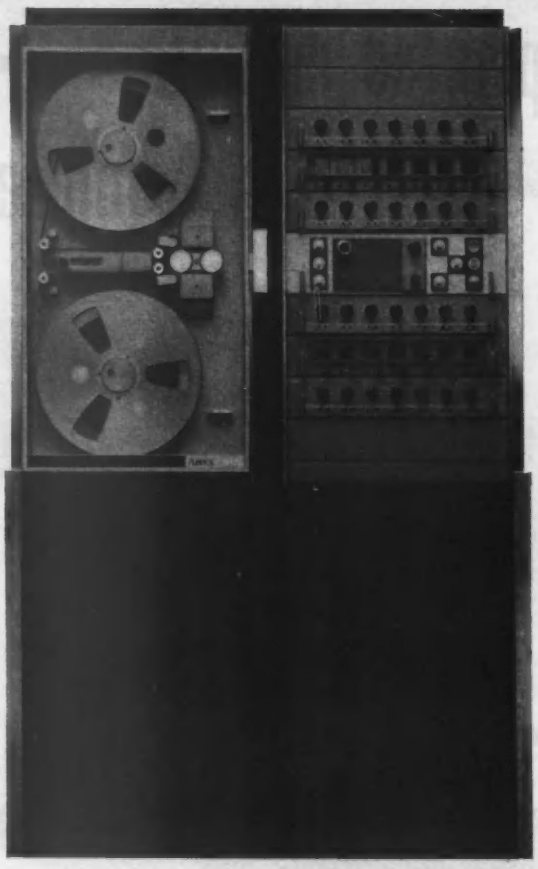

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The AMPEX CP-100 is a compact, extended-frequency instrumentation tape recorder/reproducer. Tape transport, motor drive amplifier, heads, power converter, controls and all-transistorized plug-in record/reproduce electronics are contained in a single 13¼" x 19" x 33¼" mobile case. The CP-100 operates on 28-volt DC, with 48 to 400 cycle converters available for other power sources. Data is recorded by direct or FM carrier techniques on up to 14 analogue tracks. The CP-100 offers frequency response to 200 Kc at 60 ips or expanded recording time of 24 minutes for 100 Kc data at 30 ips on a standard 10½" reel. Transport tape speeds – 1⅞, 3¾, 7½, 15, 30 and 60 ips – and plug in frequency determining units and equalizers associated with tape speeds, may be quickly changed. The versatile and mobile CP-100 performs reliably over a temperature range of from −50° F to +160° F, up to an altitude of 10,000 feet, in relative humidities to 95%... and is designed to withstand shocks and vibrations encountered in rugged mobile testing applications. This recorder may also be rack mounted if desired. For complete details write Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

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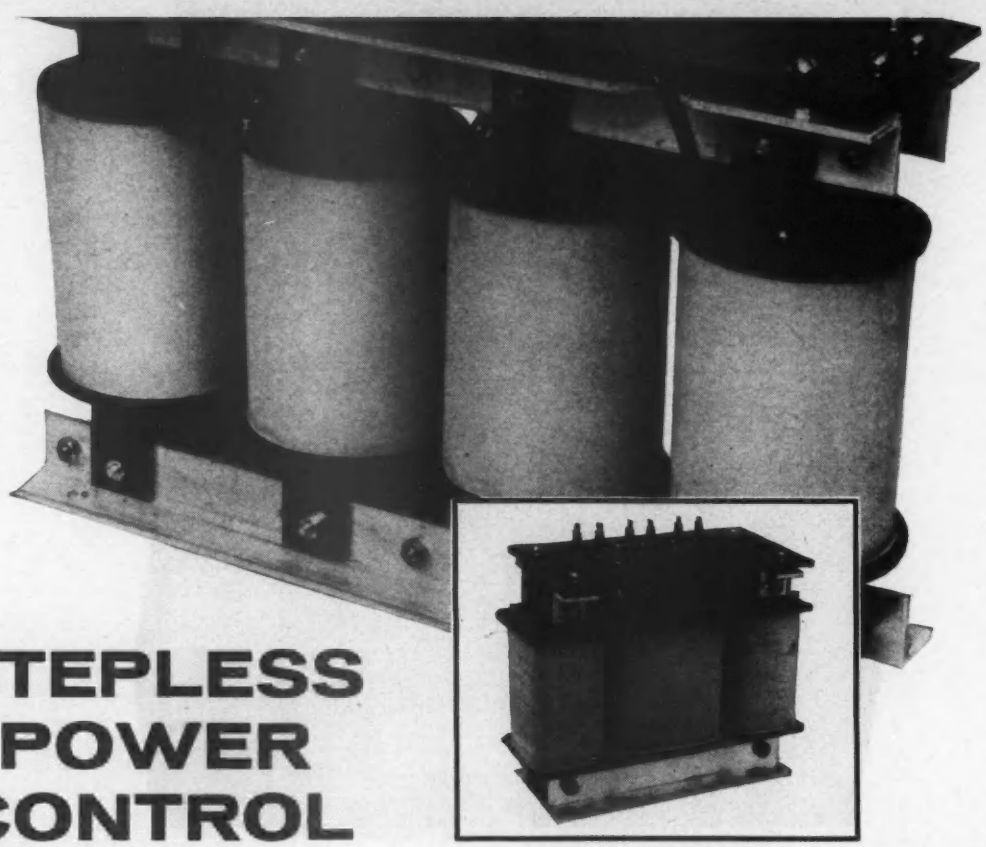

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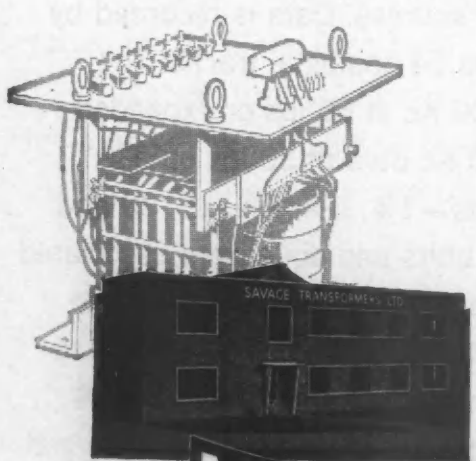

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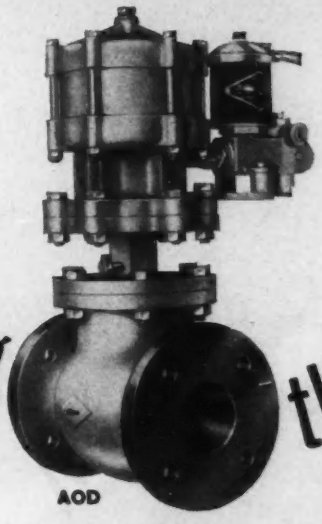
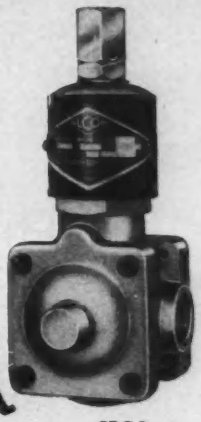


AOD



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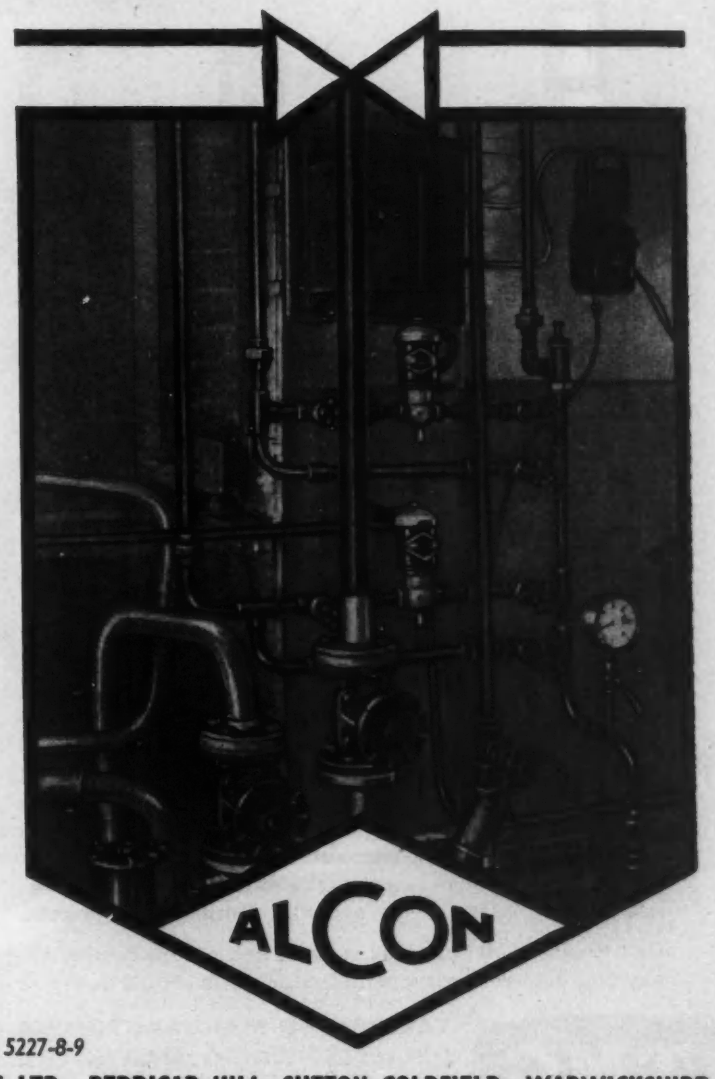

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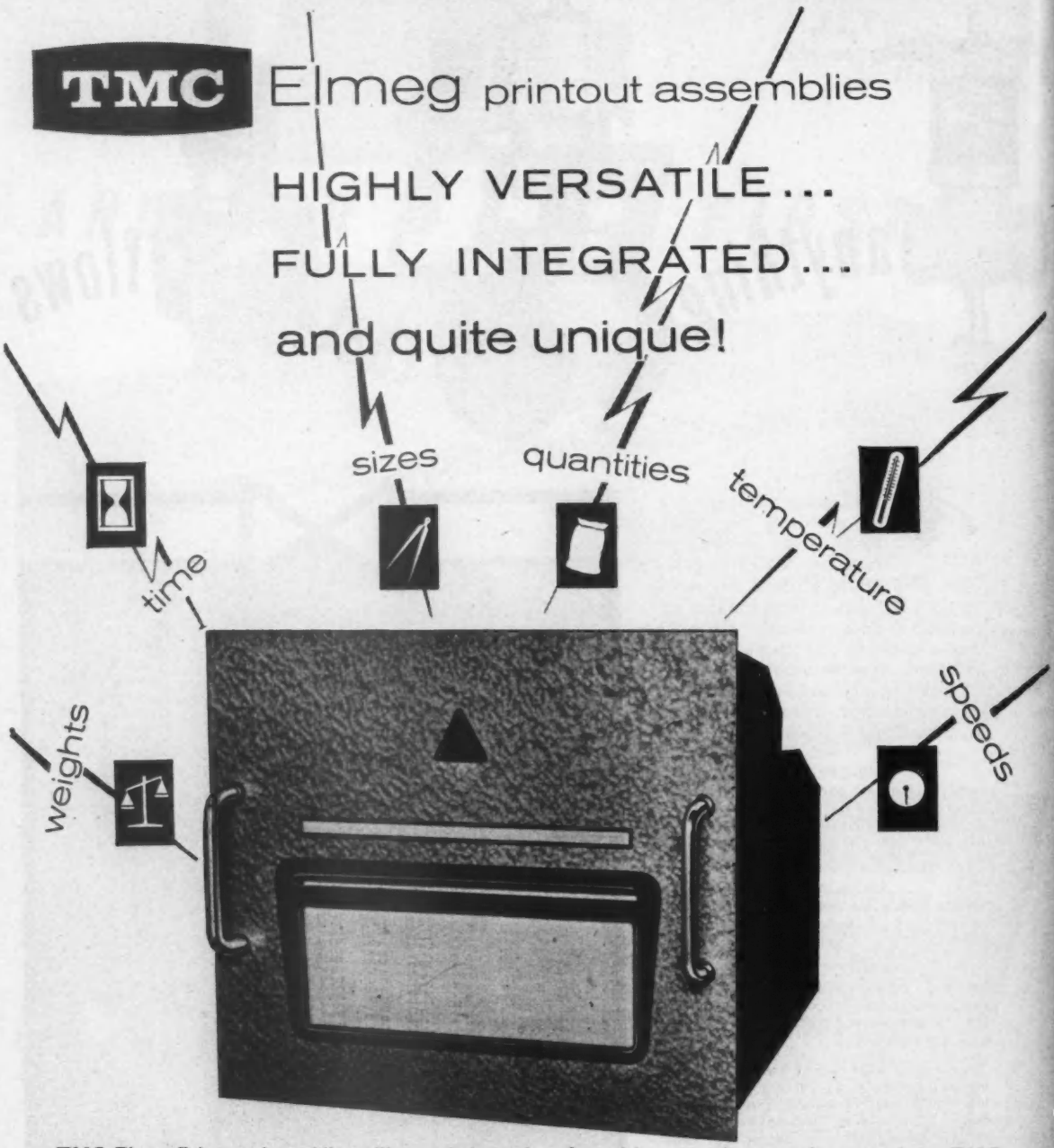

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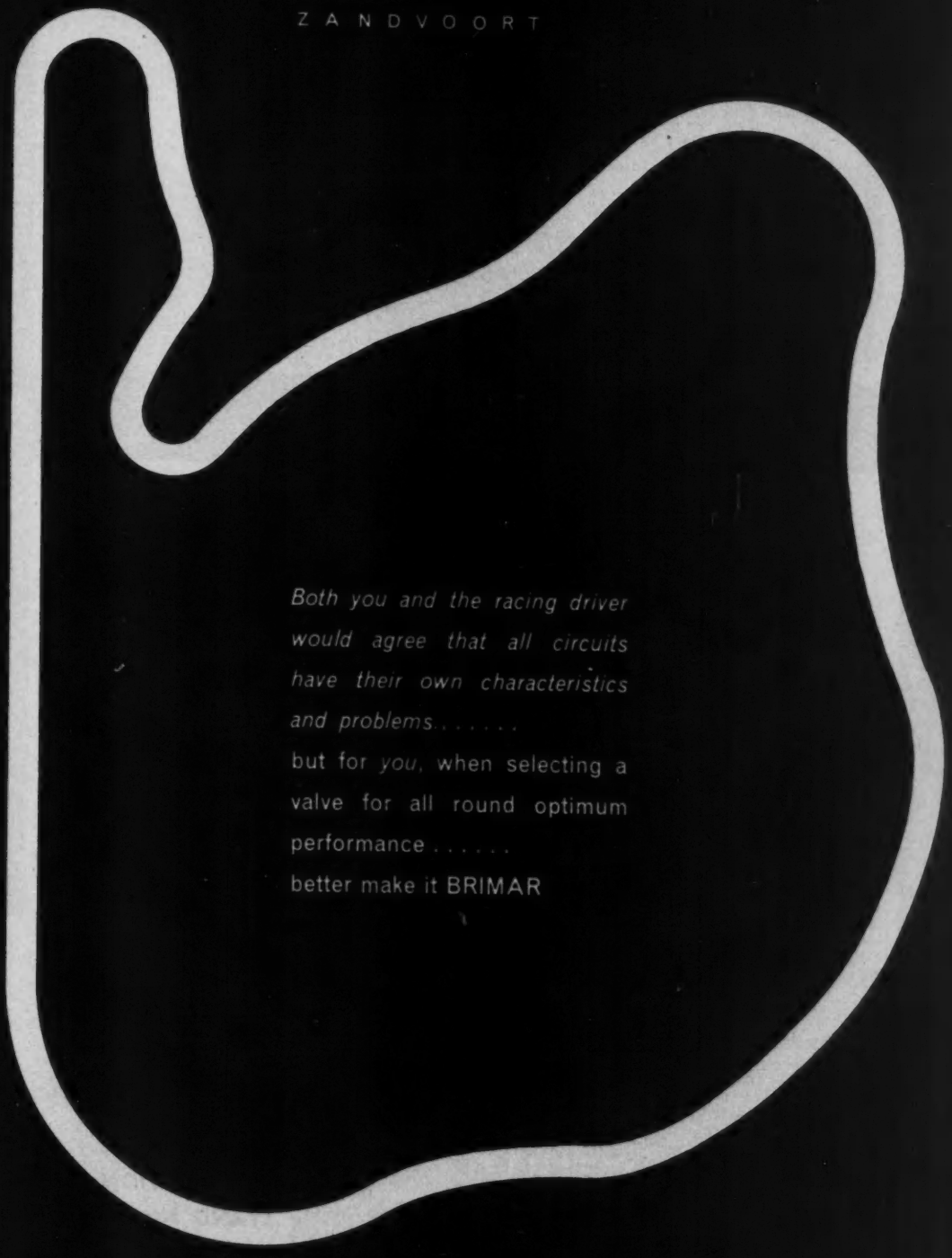

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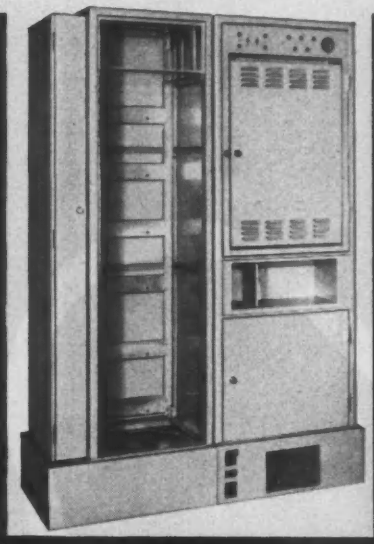

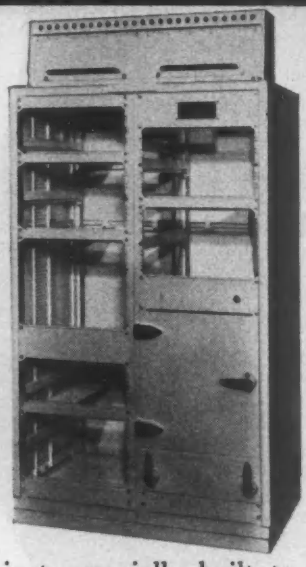

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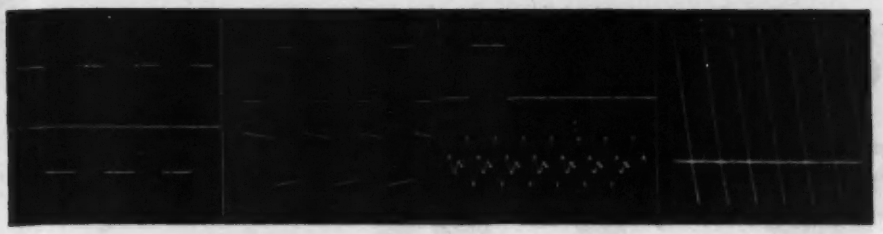
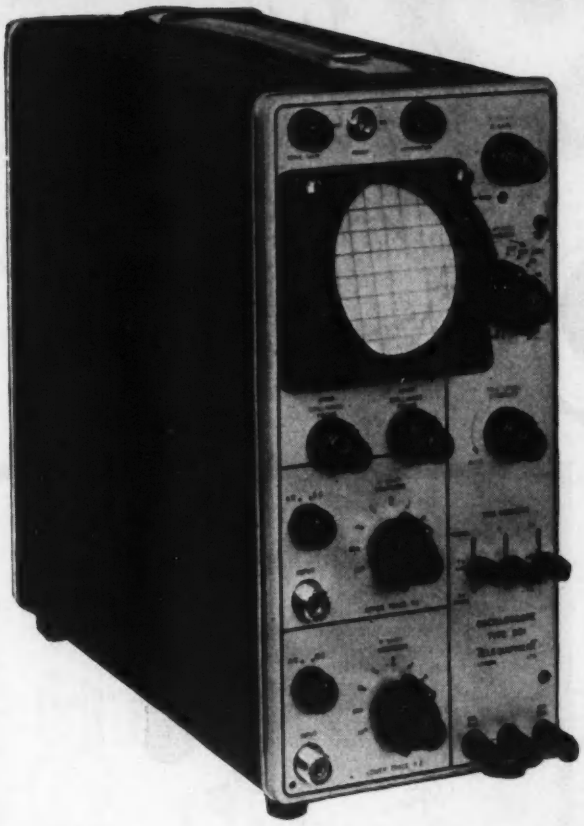


D31



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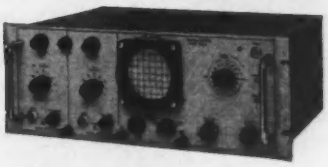

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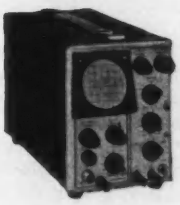

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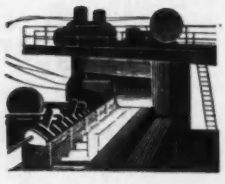
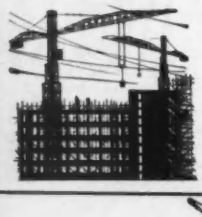
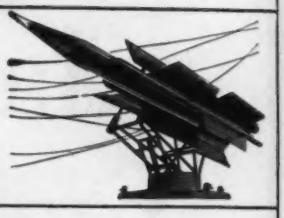
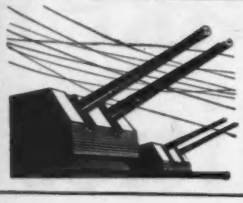




Design of heavy crane control gear

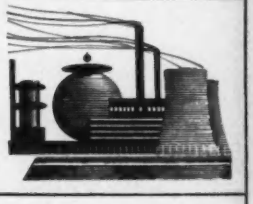
Missile servo analysis

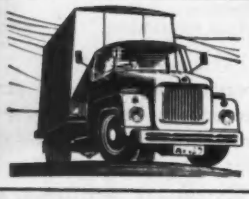




Gun control problems

Reactor control mechanisms





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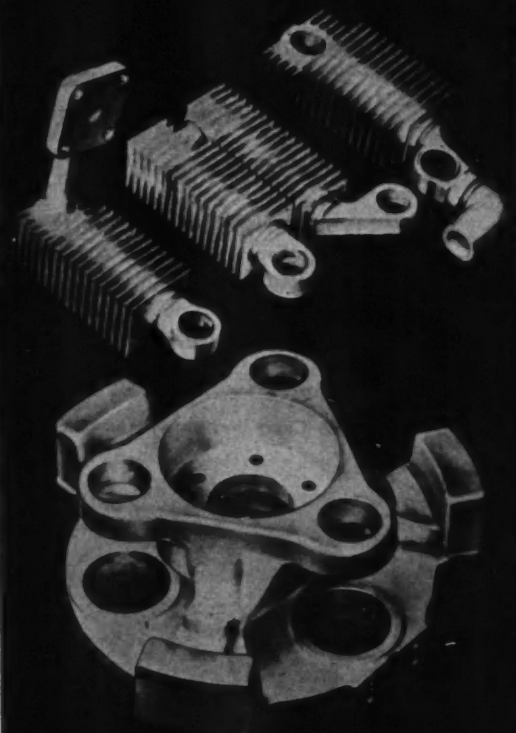

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Type 2000: Two-position on/off control

Type 2001: Anticipatory control

Type 2002: Proportioning (electrical) control

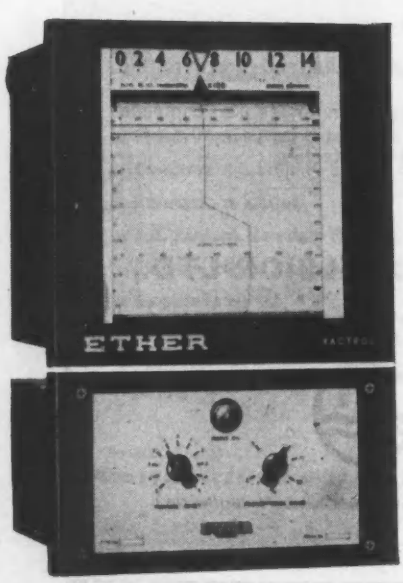
Type 2003: Three-position control

Type 2004: Programme control

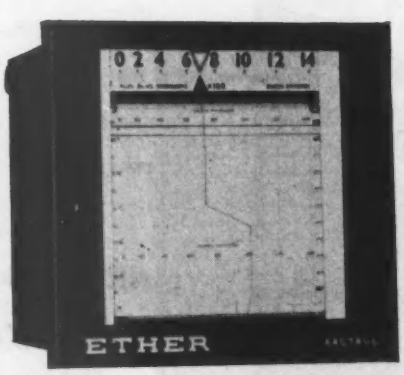
Type 2005: Proportioning (motorised) control

SPECIAL FEATURES:

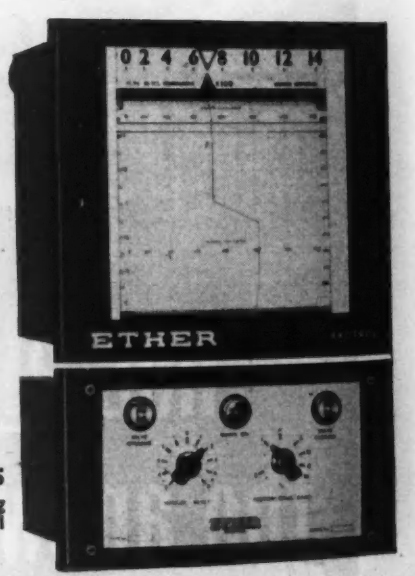
- Interruption of mains supply to instrument automatically shuts down furnace
- 6" calibrated scale
- Standard ranges: 2mV—100mV span; other ranges to order. Changed by plug-in printed-circuit unit
- Standard pen speed: 2 secs. across chart; 1 sec. or 4 secs. also available
- Chart life: 1 month at 1 inch per hour



Type 2002
Proportioning (electrical) control



Type 2000
Two-position on/off control



Type 2005
Proportioning (motorised) control

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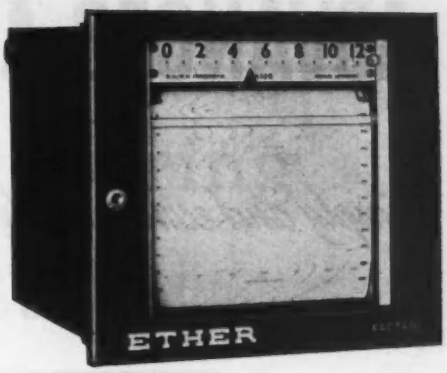
Multi-point Potentiometer Recorders

Type 2052: Two-point record

Type 2053: Three-point record

Type 2056: Six-point record



SPECIAL FEATURES:

- Balancing motor totally de-energised throughout printing and indexing cycles
- Simplified printing mechanism
- 6" calibrated scale
- Standard ranges: 5mV—100mV span; other ranges to order. Changed by plug-in printed-circuit unit
- Pen speed: 2 secs. across chart
- Printing speed: 6 secs. per point
- Chart life: 1 month at 1 inch per hour

SERIES 2500
Single-point Potentiometer Indicating Controllers

Type 2500: Two-position on/off control

Type 2501: Anticipatory control

Type 2502: Proportioning (electrical) control

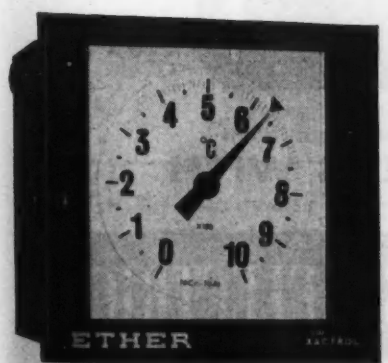
Type 2503: Three-position control

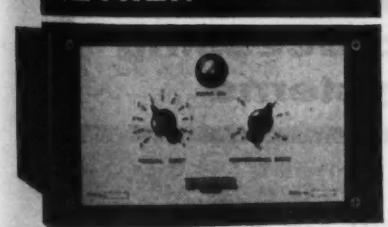
Type 2504: Programme control

Type 2505: Proportioning (motorised) control

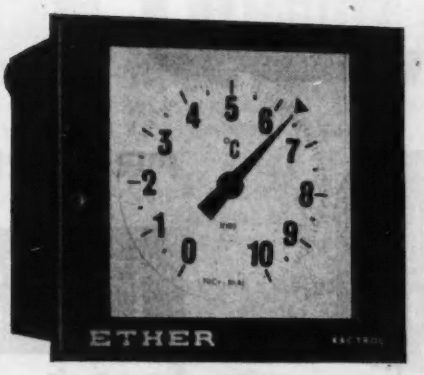
SPECIAL FEATURES

- Interruption of mains supply to instrument automatically shuts down furnace
- 18" calibrated scale
- Bold easy-to-read scale and pointer
- Standard ranges: 5mV—100mV span; other ranges to order. Changed by plug-in printed-circuit unit
- Response speed: 2 secs. across scale

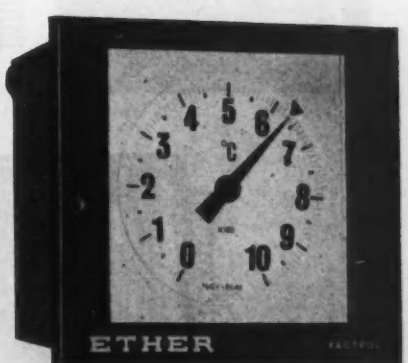


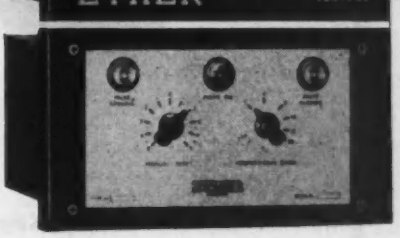


Type 2502
Proportioning (electrical) control



Type 2500
Two-position on/off control





Type 2505
Proportioning (motorised) control

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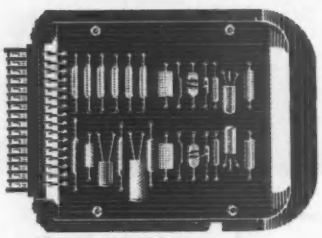

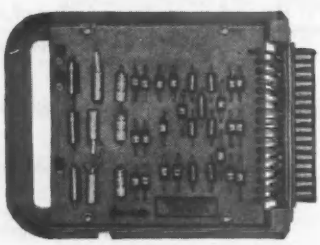

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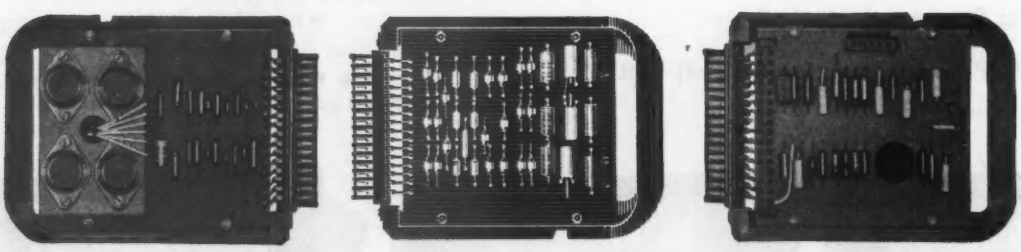

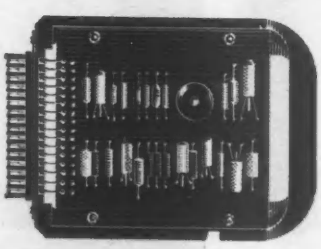

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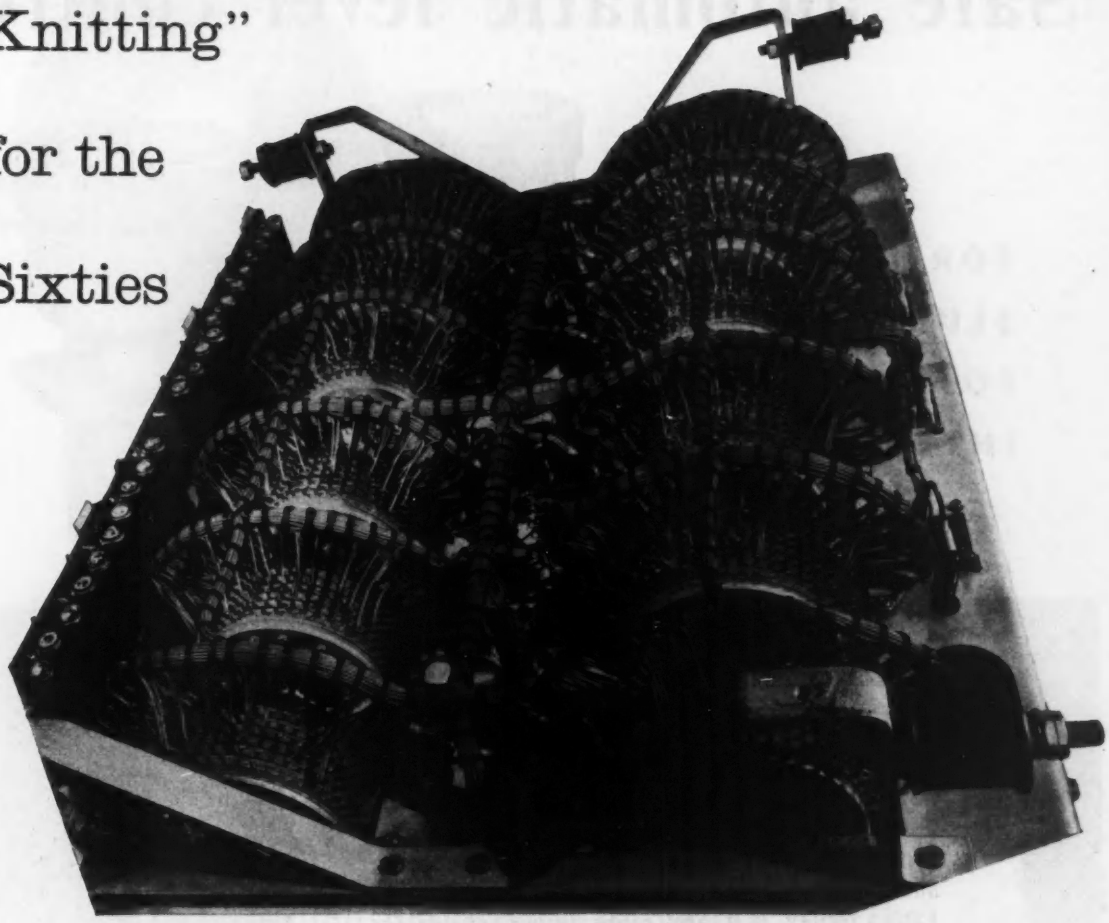

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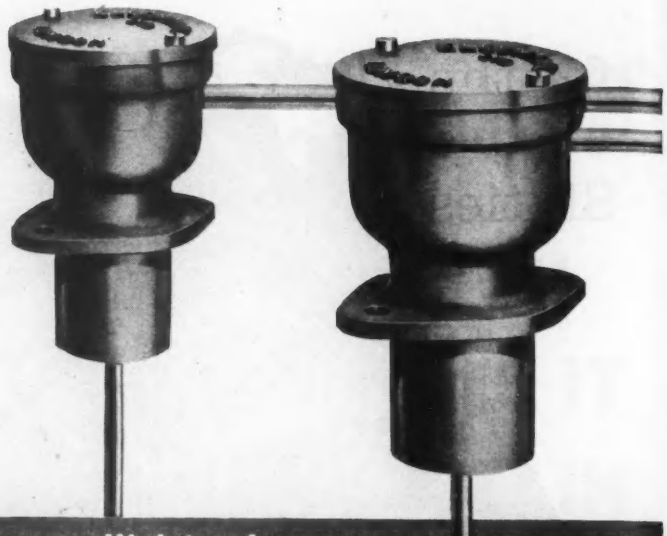

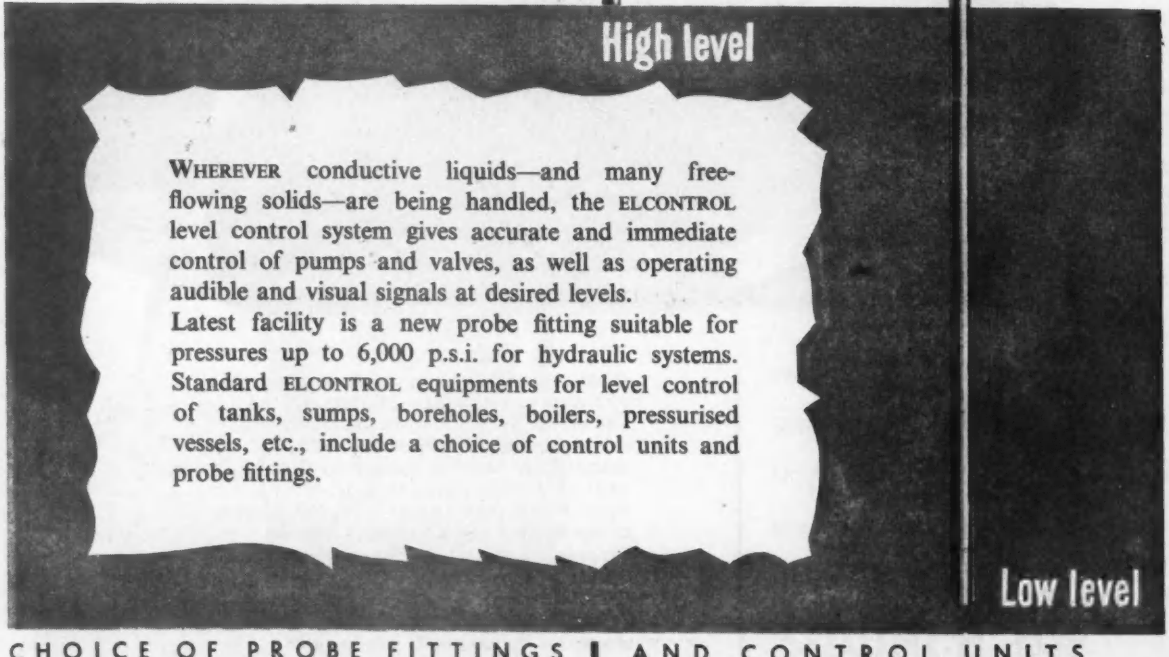

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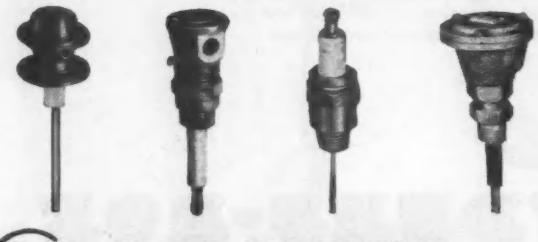

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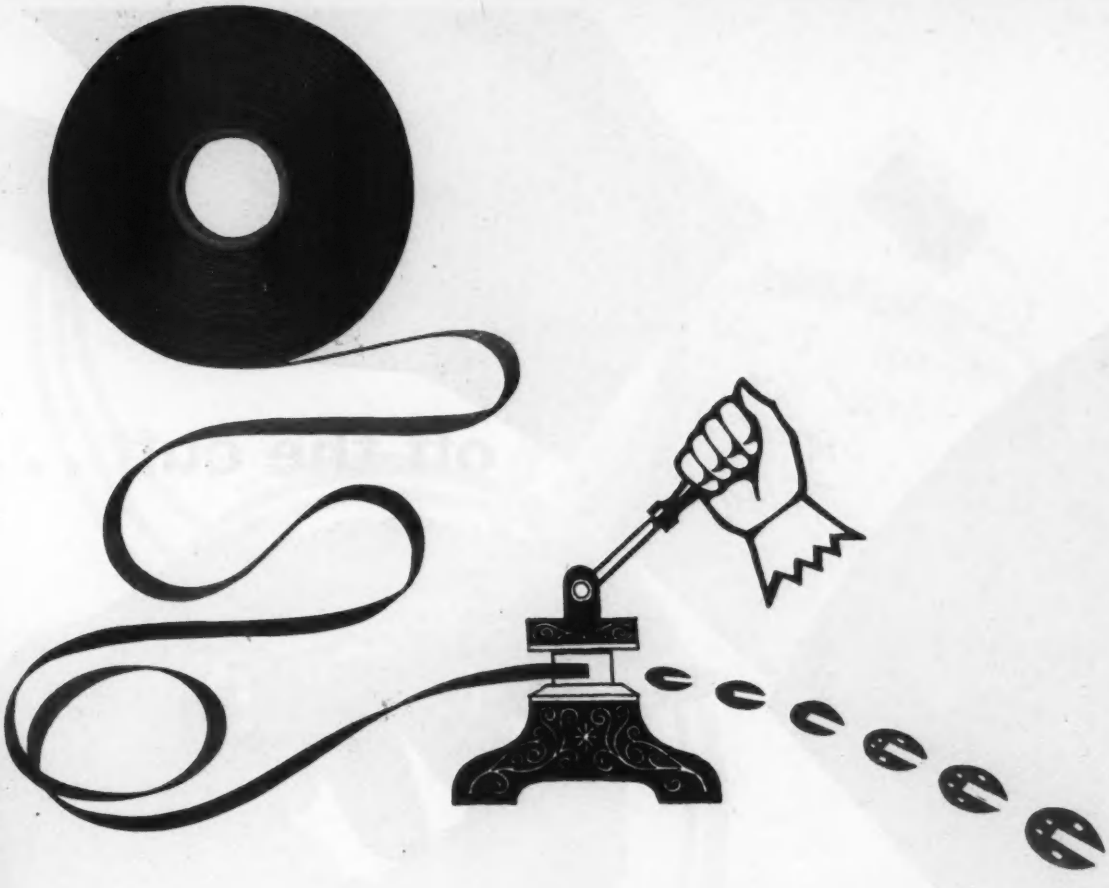

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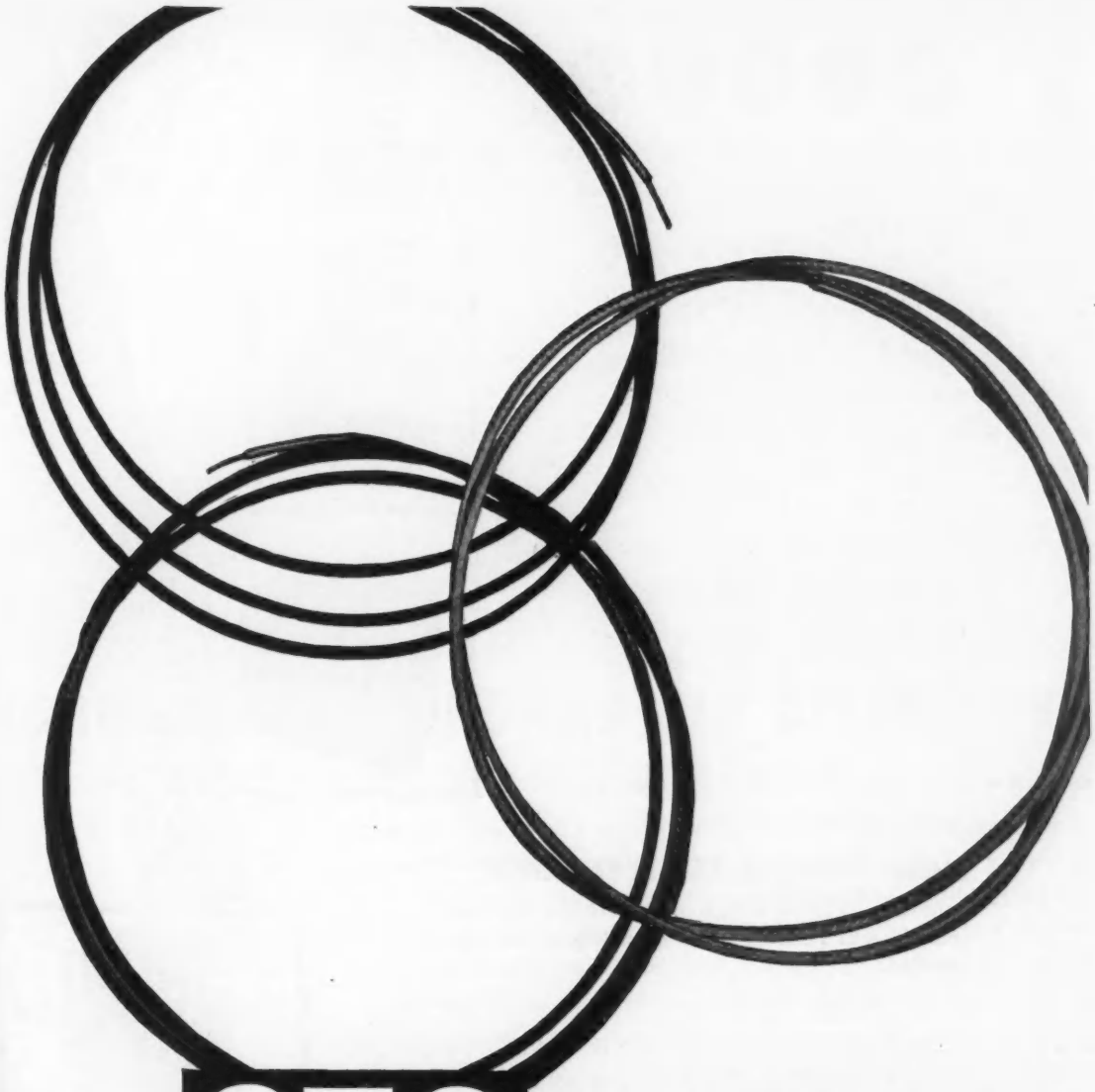

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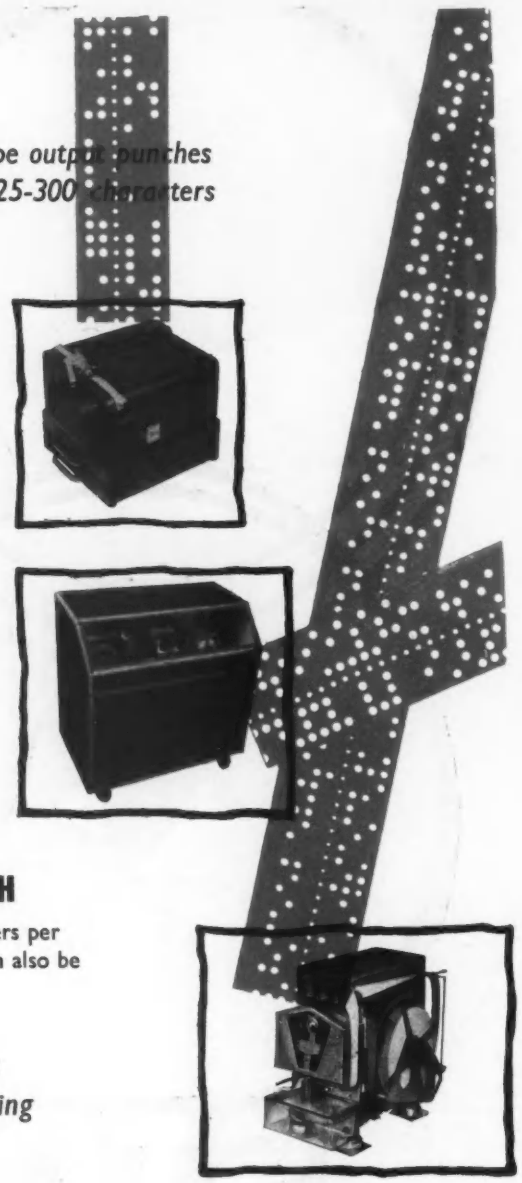

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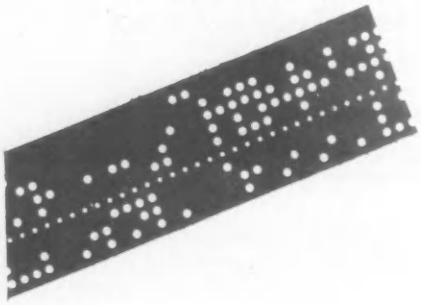

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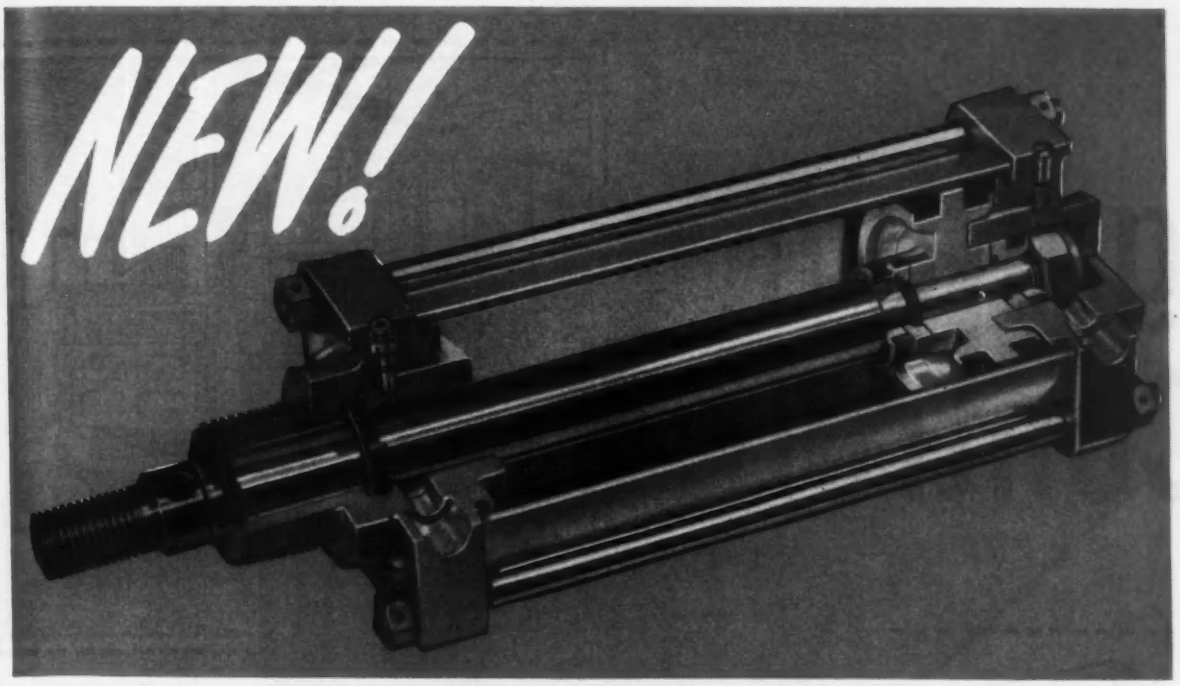

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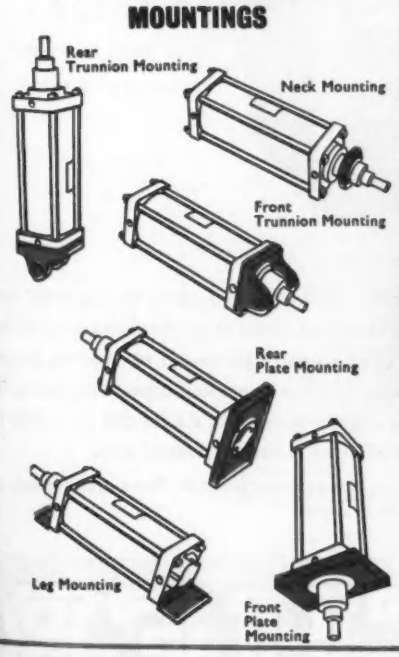

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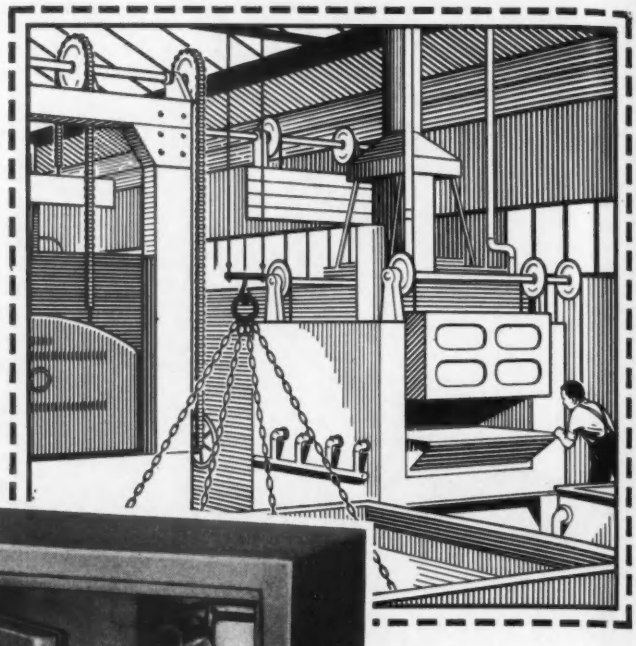

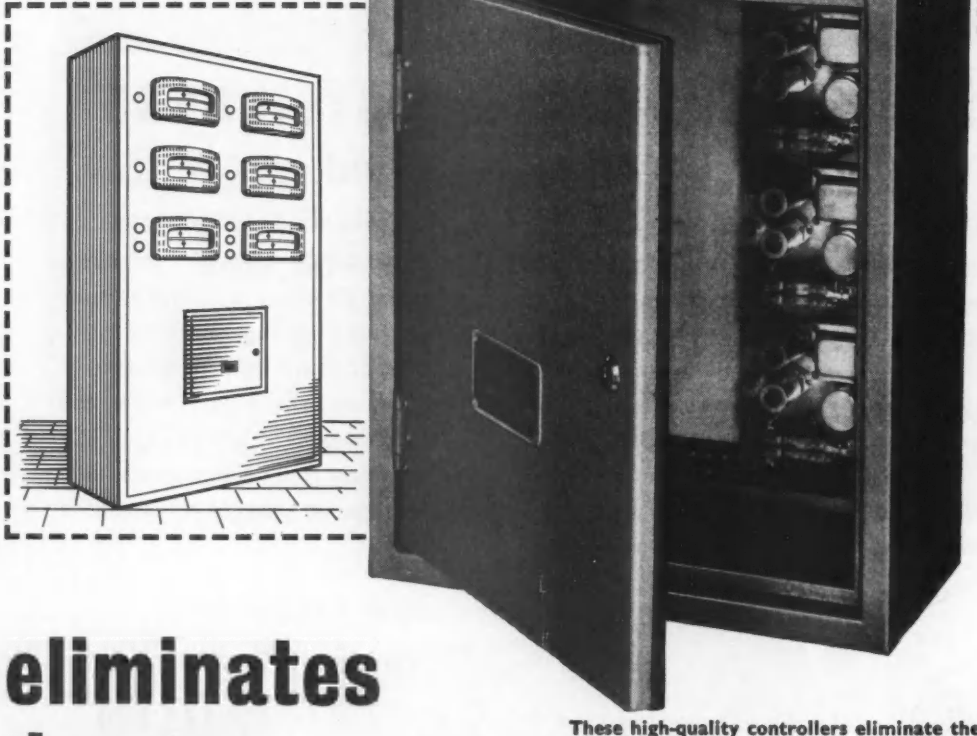

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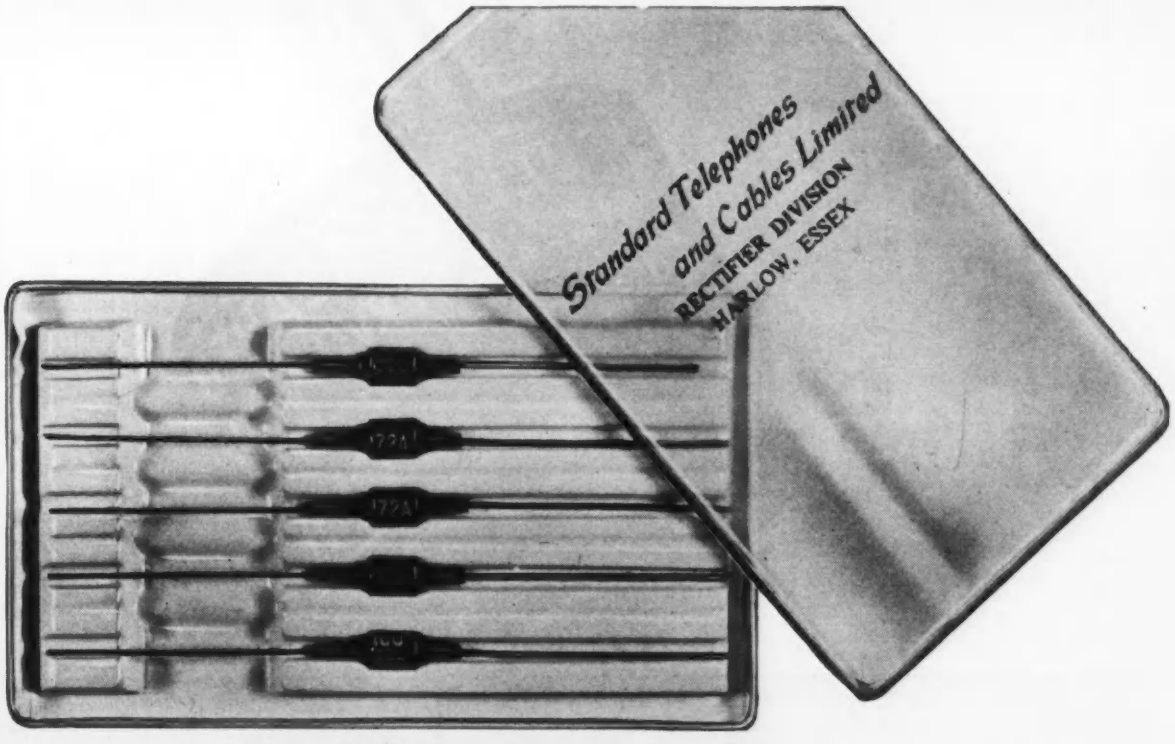
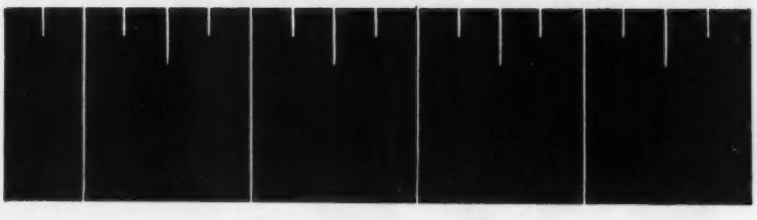


actual size



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	Z2A36F	3.6
	Z2A39F	3.9
	Z2A43F	4.3
±10% Voltage Tolerance (Red and Yellow Sleeves)	Z2A47F	4.7
	Z2A51F	5.1
	Z2A56F	5.6
	Z2A62F	6.2
	Z2A68F	6.8
	Z2A75F	7.5
	Z2A82F	8.2
	Z2A91F	9.1
±20% Voltage Tolerance (Red and Blue Sleeves)	Z2A100F	10
	Z2A110F	11
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	Z2A130F	13
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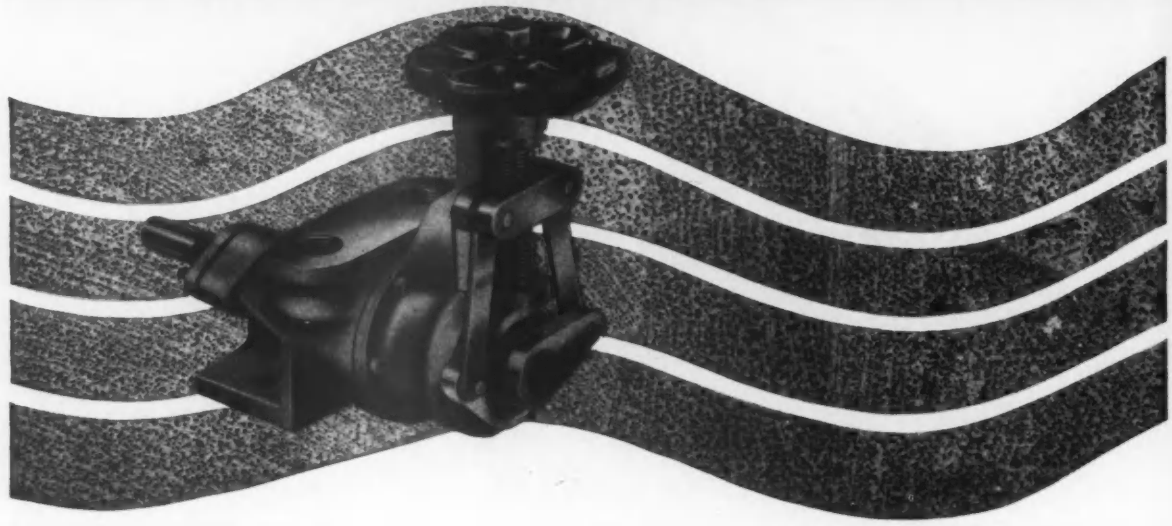

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The perfect pump for use with all lubricant fluids of a non-abrasive nature which, because of its versatility, is ideal for a wide variety of industries. Long life and reliability are built into the unique construction of the Rotoplunge, which has only three moving parts. *No other range of pumps has such a wide variety of optional features.*

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All pumps can be fitted with a relief valve and by-pass to prevent overloading of the pump or driving arrangement.

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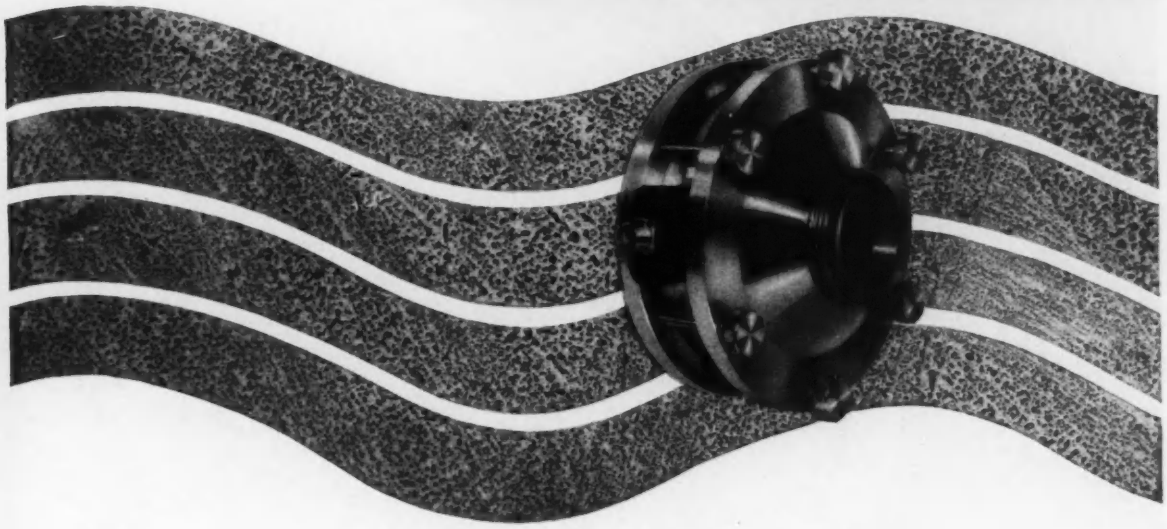

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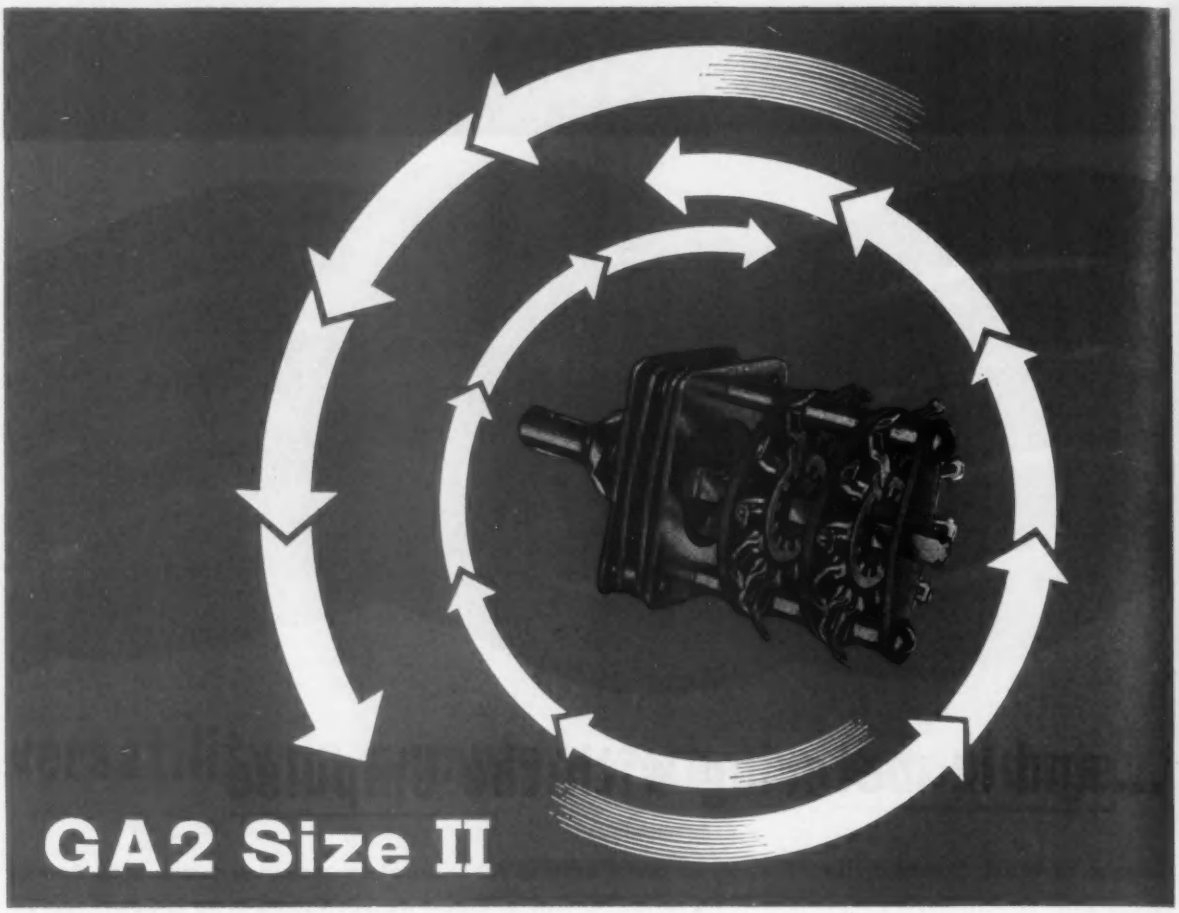

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TYPE APPROVED TO DEF. 5154

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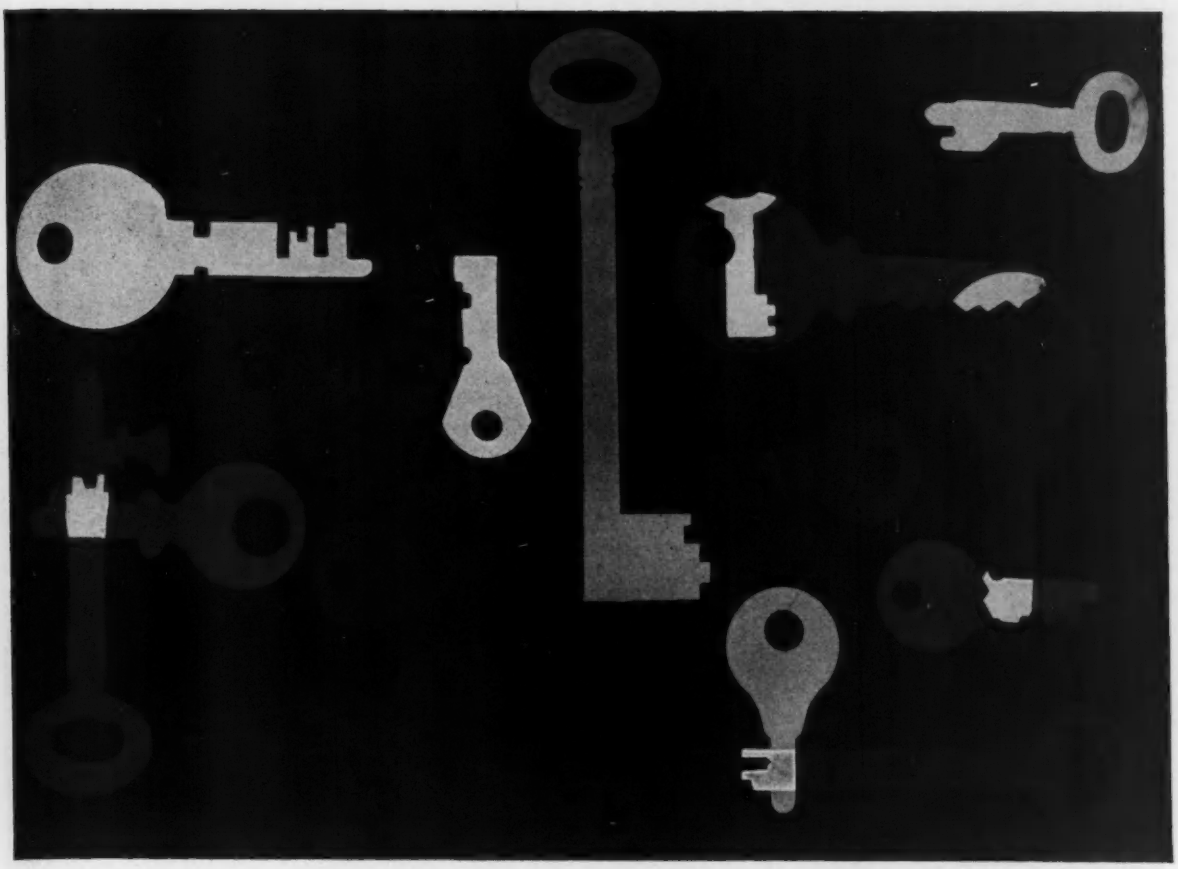

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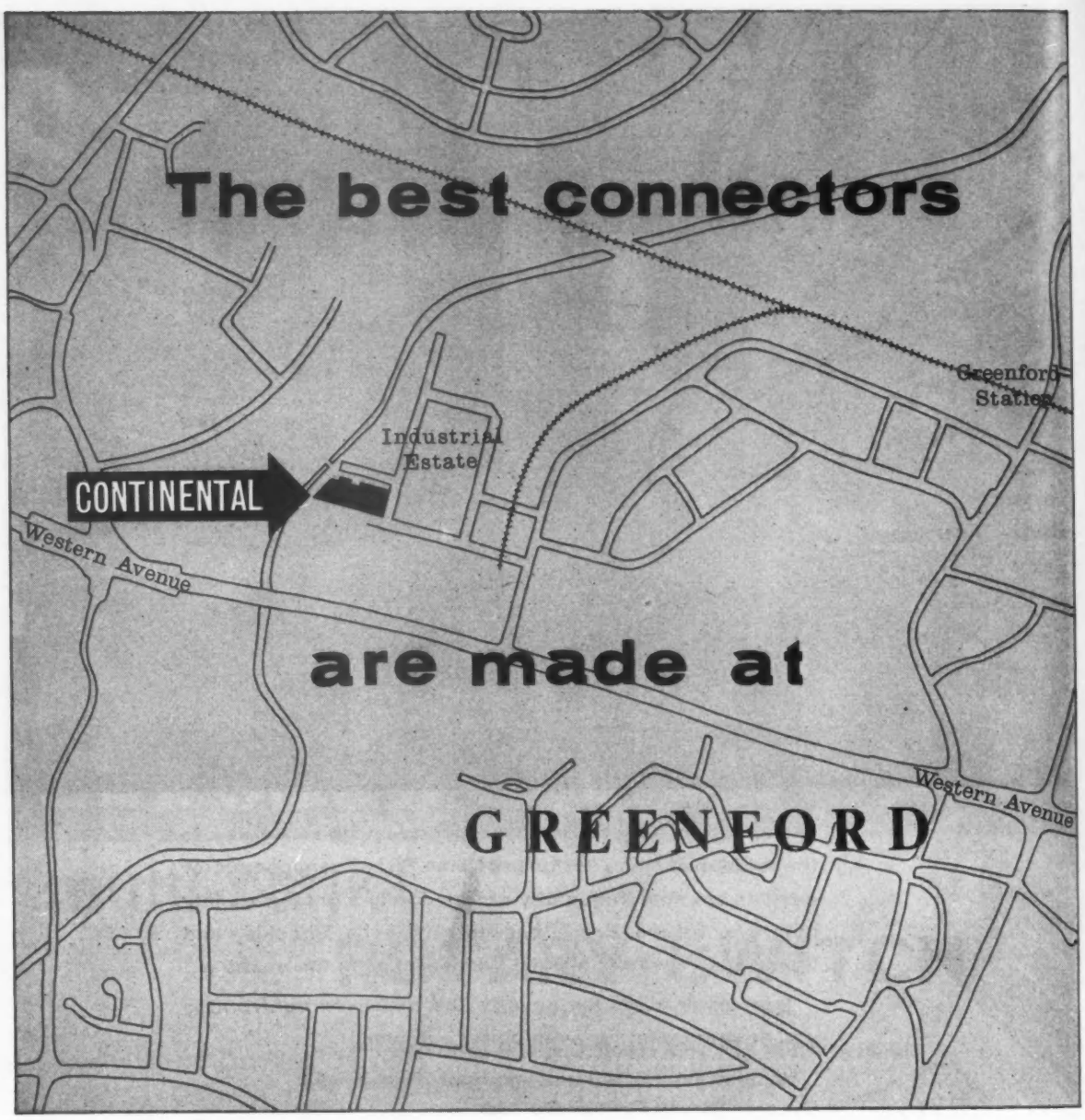

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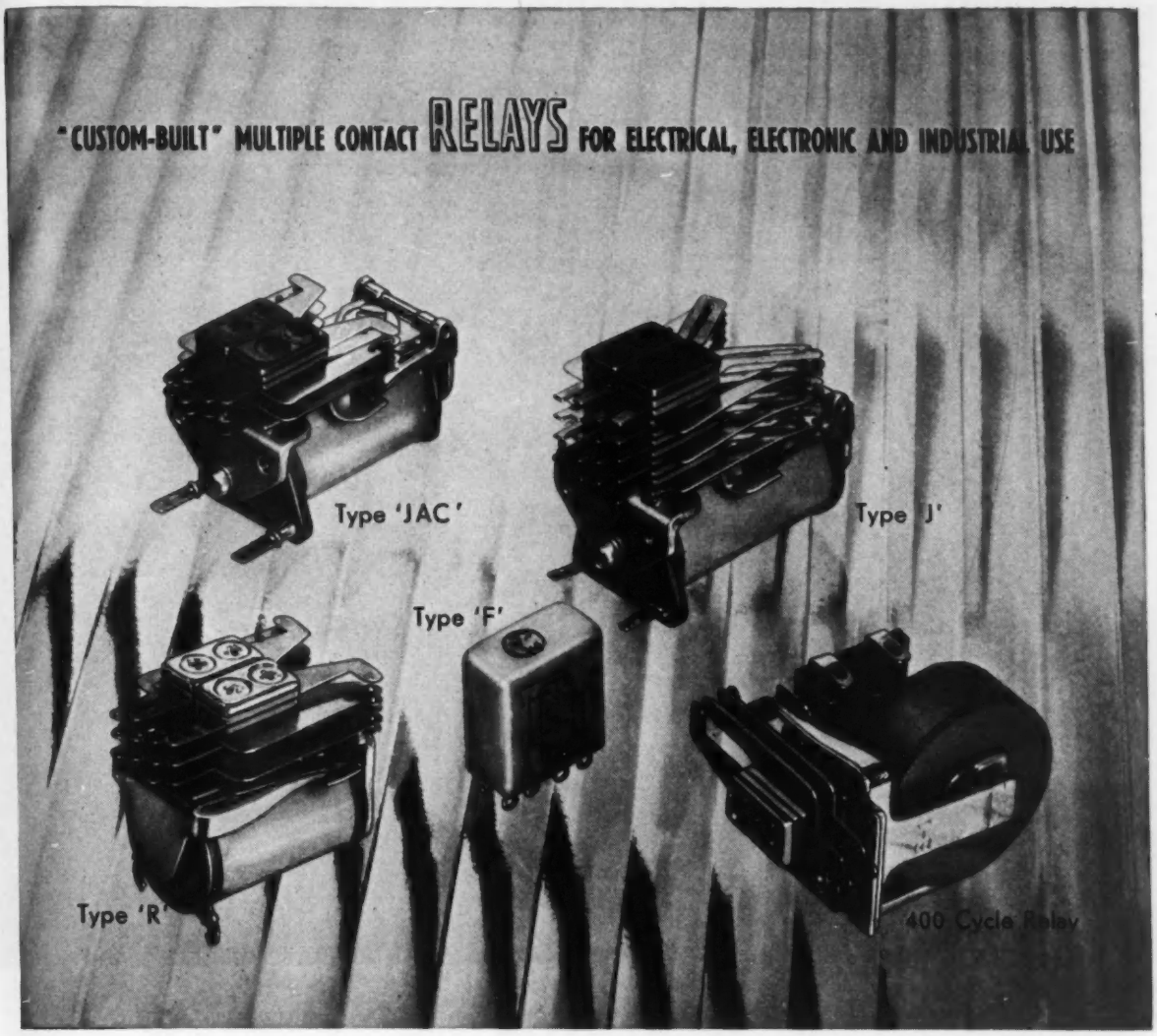

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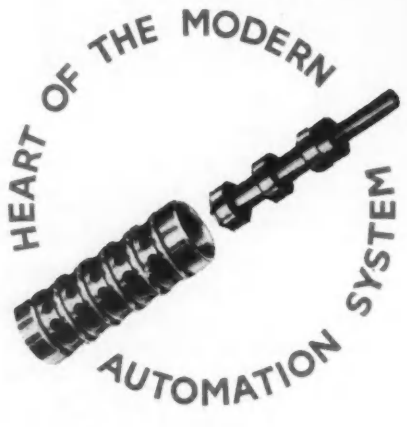

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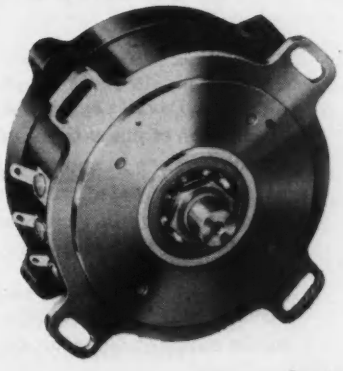

RATING	**5 watts**
RESISTANCE RANGE	**10Ω—100KΩ**
RESISTANCE TOLERANCE: Standard	**±5%**
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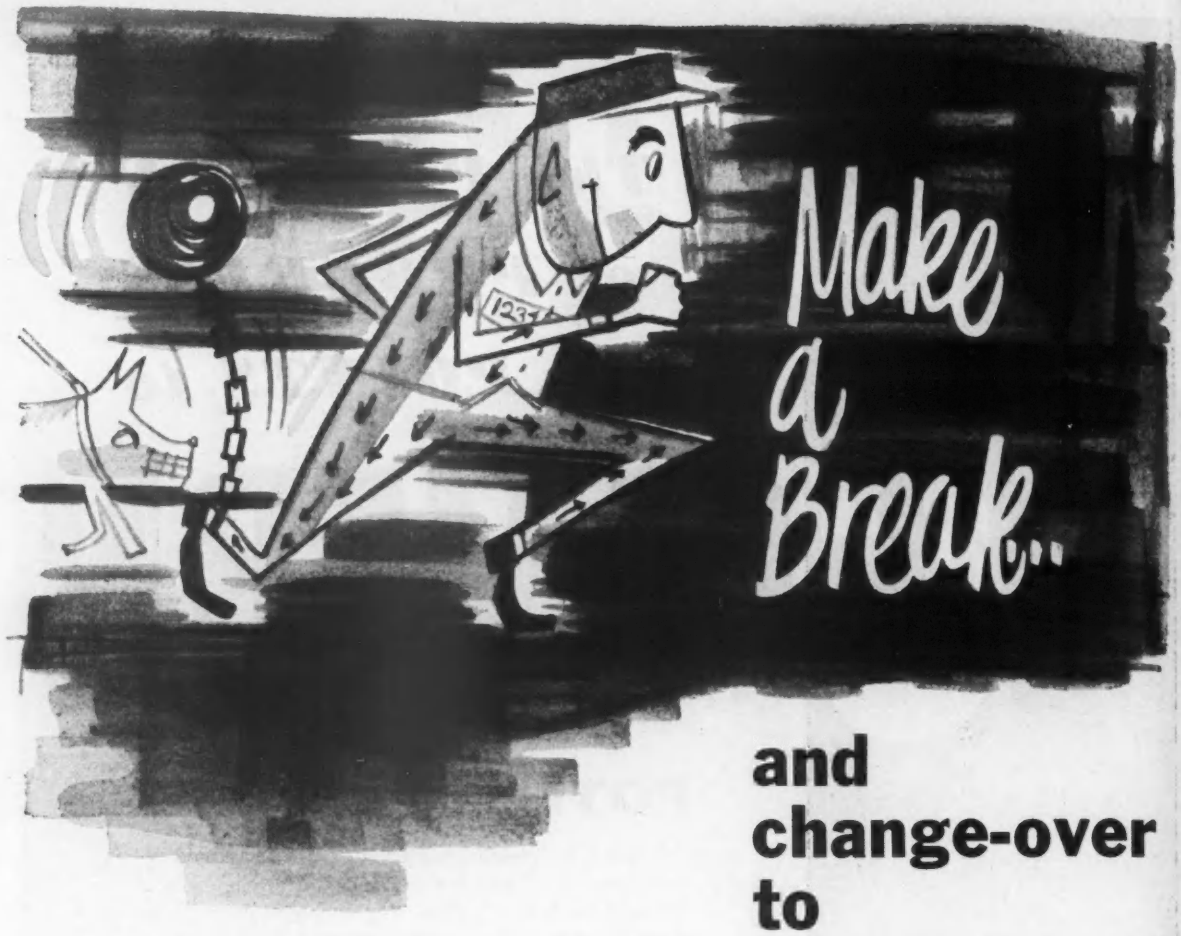

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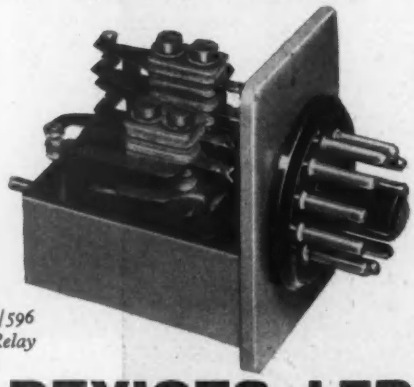

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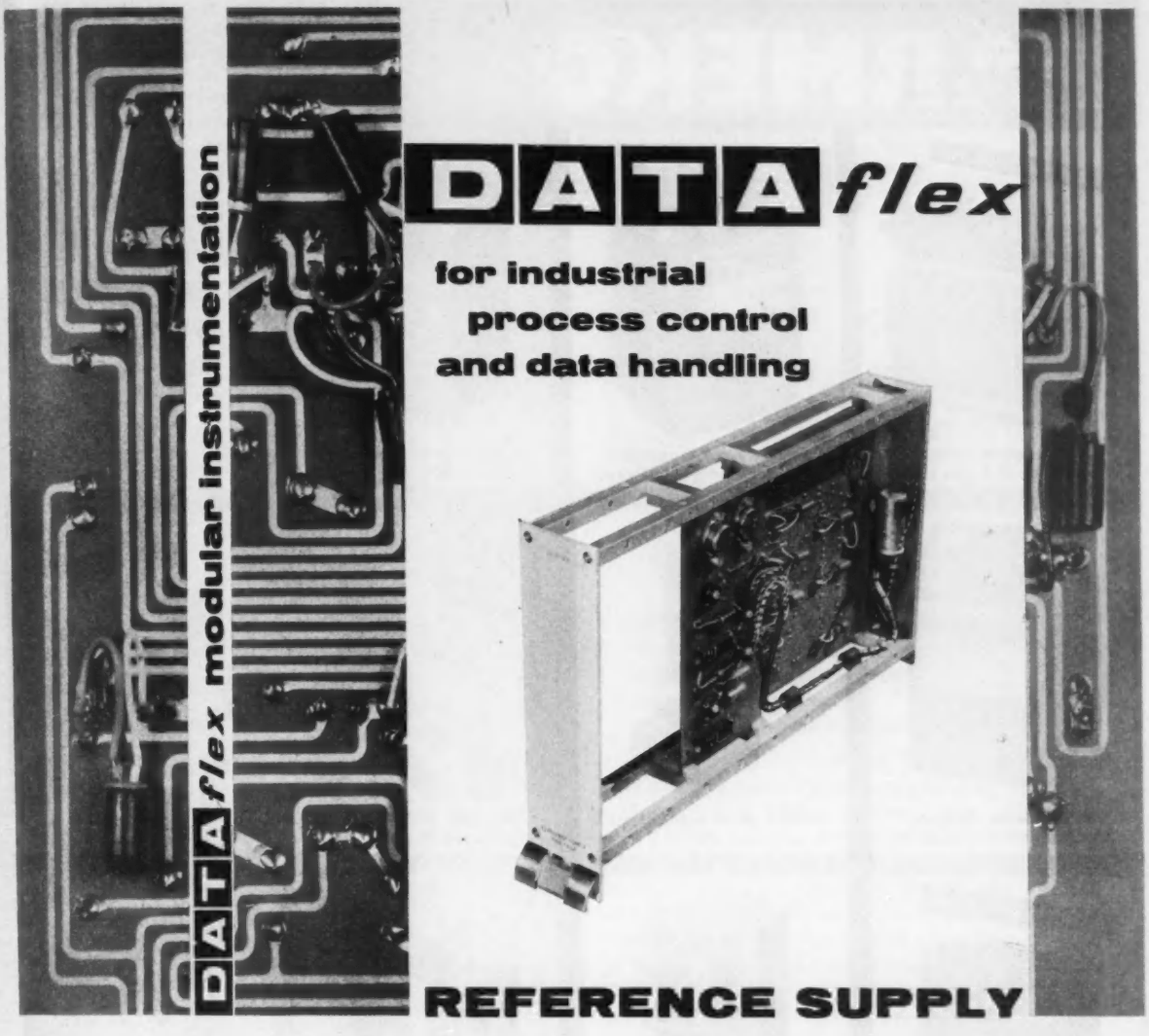

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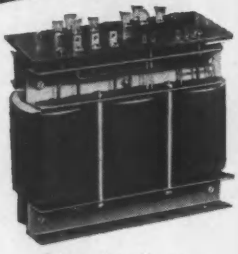

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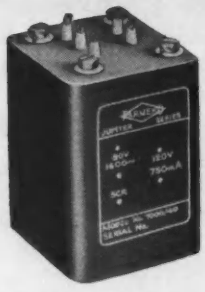

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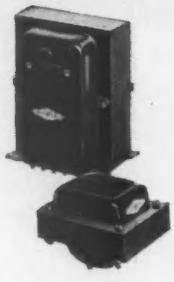

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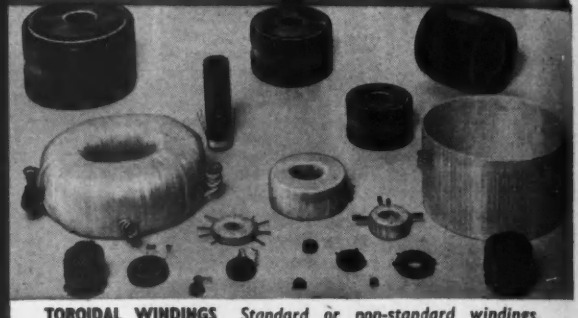

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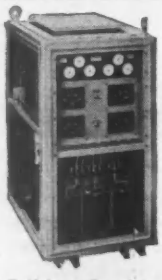
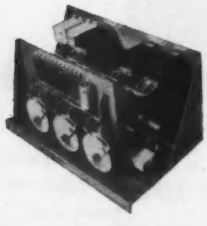


D.C. Voltage Regulators



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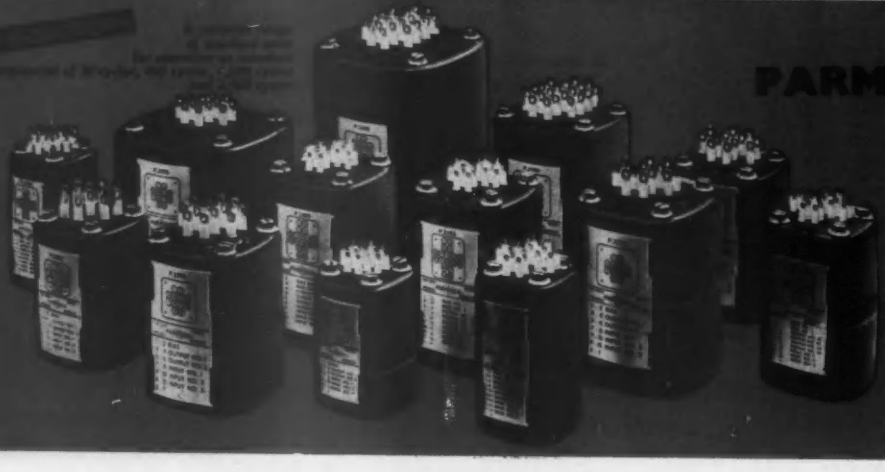
Motor Speed Control



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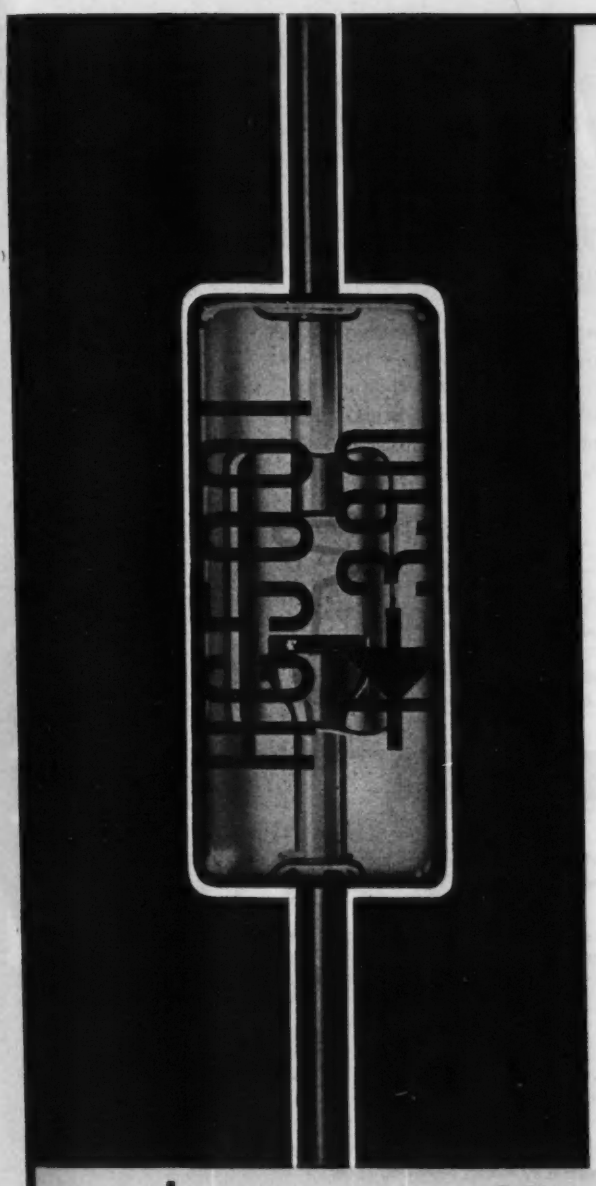

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HG5002	70	80 mA	.8 v @ 100mA	5μA @—50V
HG5003	100	80 mA	.8 v @ 100mA	25μA @—50V
HG5004	70	80 mA	.8 v @ 100mA	25μA @—50V
HG5005	100	80 mA	.8 v @ 100mA	50μA @—50V
HG5006	70	80 mA	.8 v @ 100mA	50μA @—50V
HG5007	40	80 mA	.8 v @ 100mA	5μA @—30V
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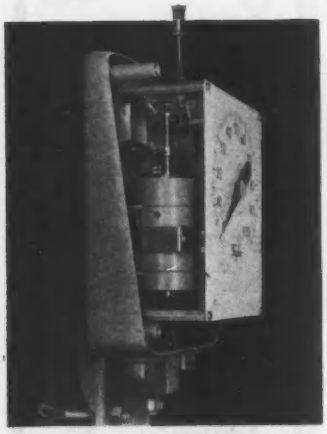

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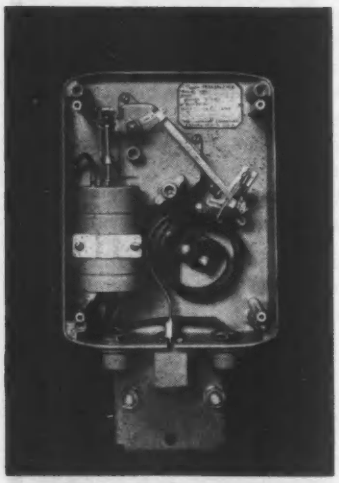

Single-package pneumatics . . . servo-powered follow-up and relay valve, encapsulated movement and actuating element are easily removable, replaceable.

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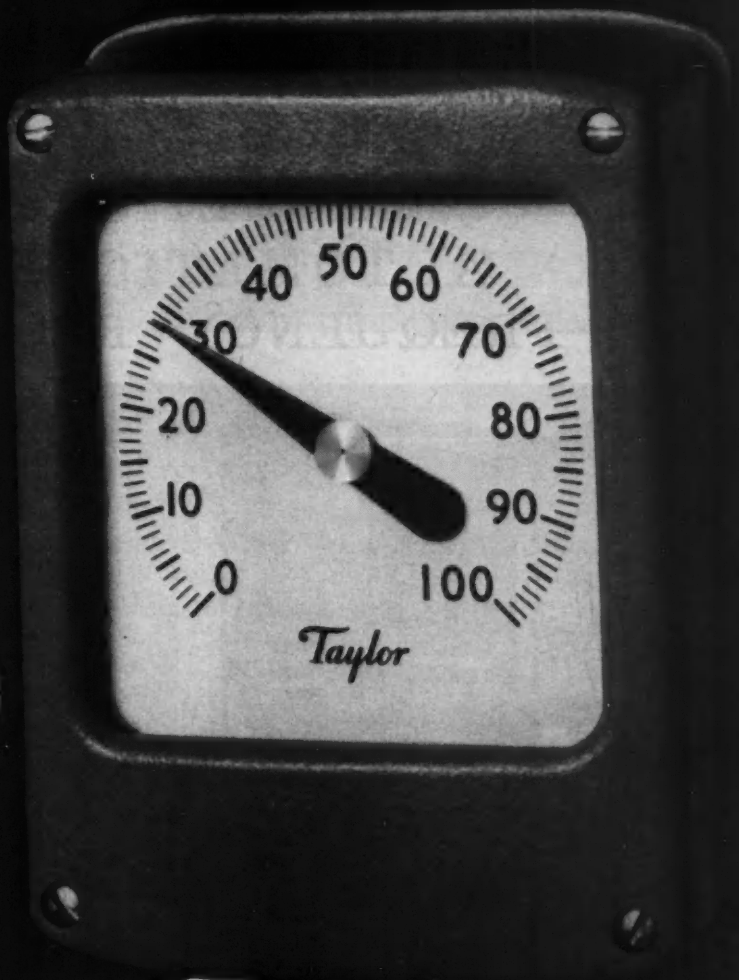

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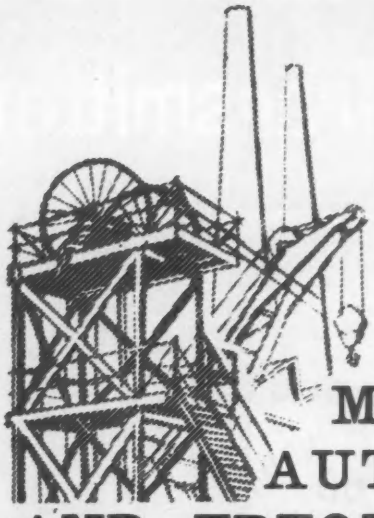

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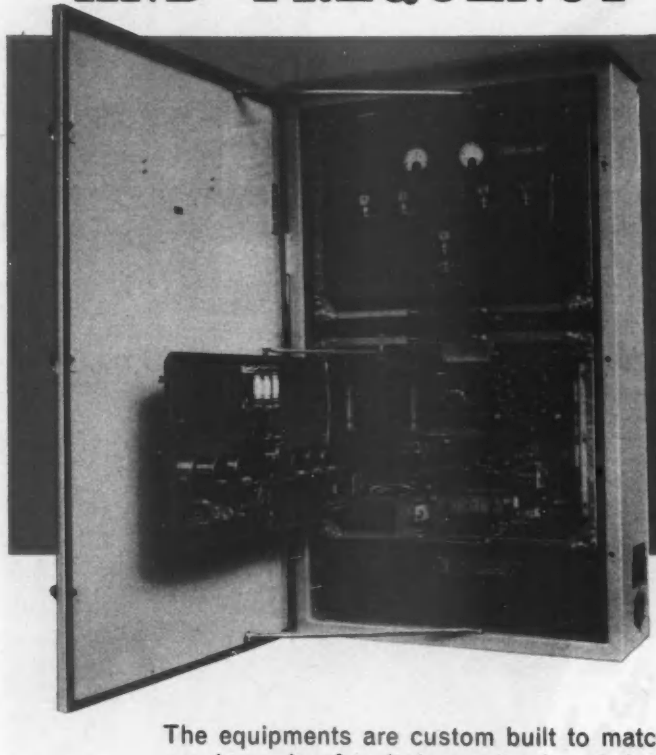

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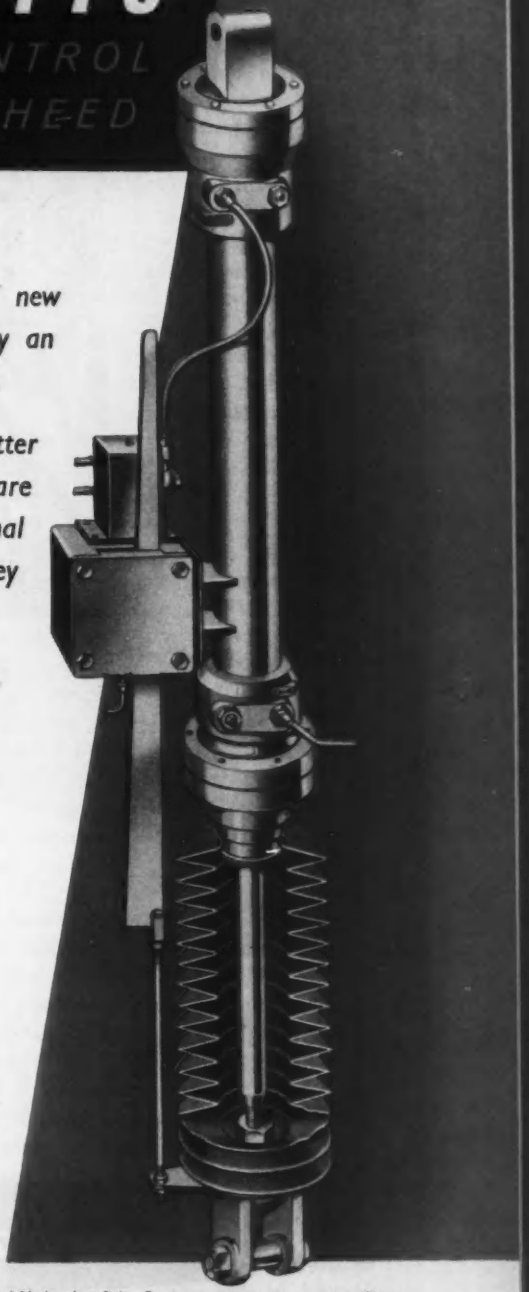

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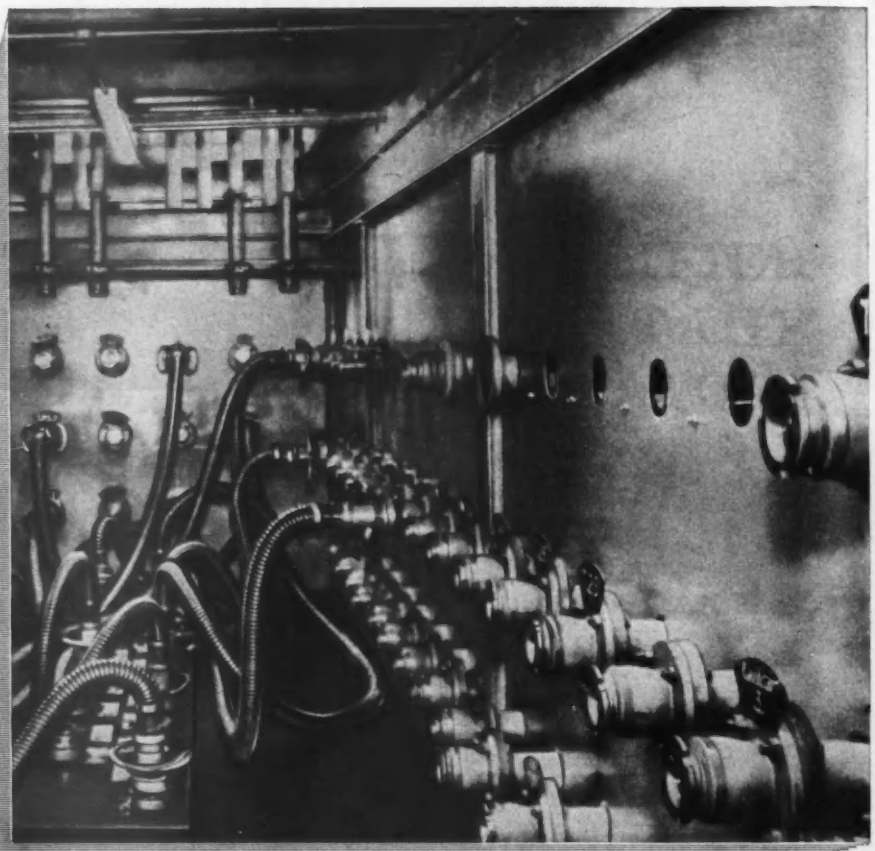

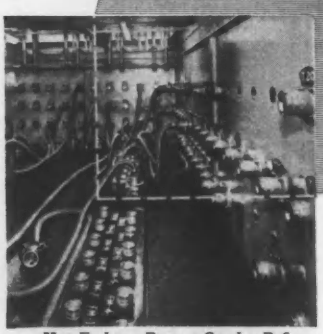

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MAY 1961 VOL. 4 No. 35 CONTROL

Survival of the fittest

AFTER A CERTAIN AMOUNT of initial fuss, the costly borrowing of an I.C.I. director for British Railways seems to have been accepted. The new man knows now, if he did not anticipate it anyway, that his position is a very exposed one. A good part of his large salary is virtually danger money, for he hazards his reputation on a labour which he must perform under constant and super-critical public surveillance. Railway users have suffered much for many years, so a measure of acerbity in their judgement is only to be expected; but looked at by the most dispassionate of observers, the railways present one of the saddest spectacles in British industry. Dr Beeching is a brave man to take the job on, for by failing he might make as sad a spectacle of himself.

Yet the railways could be set as a particularly inviting problem for the control and systems engineer. Of course *any* engineer, given sufficient means and resources to tackle this task, would be as blissfully happy as the father with the train set that he has ostensibly bought for his small boy. Unfortunately, railway systems are not provided by a paternal public for the pleasure of its more ingenious sons. Unlike weapon systems, railways are expected to work as commercial enterprises, and this makes them much less attractive to the kind of engineer who will not lift his eyes from the hardware. Control and systems men would naturally be happier with the more comprehensive task, but they would still need the sufficient means and resources to tackle it. Are such means available, or is anybody trying to find out whether they could be? It is trite to say that a good transport system is vital to a civilized modern country, but it is very difficult to go on from this truism to a clear statement of what is meant by 'a good transport system'. Is anybody concerning himself with this problem? A great deal is being said today about self-optimizing systems. Is anybody in the country trying to find the optimum for its transport arrangements? We fear that the answers to these questions are negative. The whole thing is probably being left to Nature, which is known to be rather good at evolution and especially benign toward the inhabitants of the British Isles.

In recent years there have been suggestions that the railways are due for extinction and that other varieties of transport will supplant them. Roadways are advocated in some quarters to replace (physically as well as metaphorically) the existing rail network. We do not deny that in the short term such a radical revision of British overland transport might have certain advantages, but we believe that in the longer term it would be absolute folly. Among control and systems engineers (though unhappily not among all other engineers) it is common ground that the trend must be toward a more and more automatized national effort, and industrial systems will inevitably become integrated to an ever greater extent. Integration on a tremendous scale is becoming possible because of the rapid progress in data handling, and centralized computer control of transport networks is a manifest possibility for the not-so-distant future. Obviously a railway system is a much better prospect for full, or even partial, automation than a mesh of roads filled with scarcely governable traffic.

As we go to press, engineers from many parts of the world are about to meet in London for a discussion of railway modernization generally. This conference has been arranged by the Institutions of Civil, Mechanical and Electrical Engineers and has been announced as an event of very great importance. We heartily agree on this rating of the subject, though we are depressed by the absence of other B.C.A.C. bodies from the organizing group. In particular, we should have liked to see the Society of Instrument Technology represented. To us, the control and systems engineering approach seems essential if the problem as a whole is to be tackled in an appropriate way. We hope that something of the spirit of the age will have informed the conference, and that it will not be long before British railwaymen break out of their excessively inbred fraternity to discover what has been happening in the great world. They should know that 'automation' is more than merely a journalese word. If they will not learn its full implications then Dr Beeching's job will be just so much more unenviable, and the Law of Natural Selection will do the rest.

LETTERS to the EDITOR

Pounds and pounds

SIR: In his letter published in the February issue of *Control*, Mr. Helmer obviously intended to clear away the considerable confusion which surrounds the British system of units; however, in his desire to throw out the troublesome "g", he has thrown in a "32·2" which is likely to prove even more troublesome!

I was a very fortunate young engineer in that during my apprenticeship I took simultaneous courses in electrical and mechanical engineering, thus forcing me into getting my ideas on "engineer's units" completely straight right from the moment I entered College. I was doubly fortunate in that the Rationalised M.K.S. System of units had been adopted by the Department of Electrical Engineering shortly before I arrived (this relieved the student of the responsibility of inserting the 'ten-to-the something-or-other fiddle factor" into his equations when his answer was in error by several orders of magnitude!), and triply fortunate in that throughout the Department of Mechanical Engineering, the Foot, Slug, Second System was used.

To return to the issue at hand, Mr. Helmer states quite rightly that "mass and weight are as different as the proverbial chalk and cheese", so why not accept this fundamental difference rather than try to even things up with a 32·2? The weight of a body is the force produced when it is acted upon by some acceleration; the acceleration due to gravity is ever present so it is only natural that when the word "weight" is mentioned, one immediately thinks of the force on a body resting on the earth's surface where the acceleration is 32·2 ft/s², or thereabouts. However, what happens if there is a change in the applied acceleration? Obviously, the mass of the body remains constant but the weight changes. The new weight may be determined by measuring the force produced by the new acceleration; we can now see clearly the difference between mass and weight. The mass of a body is given by $M = W/a$ where M is the mass, W is the weight, and a is the acceleration *under which the weight is measured.*

This relationship is true even at some point in space or on some other planet where the local gravitational acceleration is not 32·2 ft/s²; the mass of the body may be found by weighing the body on the same spring balance that was used on earth and dividing the weight by the local acceleration. It can clearly be seen from the above that the factor of 32·2 must *only* be applied to a body at rest or in uniform motion on, or close to the surface of the earth when converting from weight to mass.

Now that we have exposed "g" as being just another acceleration, we are free to consider whether to rationalise or not to rationalise. As every student knows, constants of proportionality have a habit of getting on top of an expression when they should be on the bottom, and *vice versa;* it is obviously better in the long run to eliminate these constants by using a rationalised system. The use of lbf as the unit of force is almost universal amongst engineers (except where the metric system is in use), so there is little point in trying to get universal recognition for the poundal; the latter is rather small for practical purposes, anyway. Since adopting "g" as the unit of acceleration would introduce a further problem (that of converting from ft/s² to "g" and *vice versa*), the obvious way to rationalise is by taking the slug as the unit of mass. Mr. Helmer's argument that the slug "does not really exist" is hardly a valid reason for not adopting it; I for one find the slug a far more real unit than the pound mass since I was reared on it! Furthermore, in a very large number of practical cases, mass is not even used since the engineer is primarily concerned with the weight of body, i.e. with the force required to support it (on earth); thus rationalisation by choosing a suitable unit of mass causes a minimum of interference with the units already in use.

Whether Mr. Helmer agrees with the above or not, I am sure that he will agree with me that the real danger in our system of units is not in its use but in its *misuse.* All too often, pounds force are "cancelled" with pounds mass; the rocket engineer quotes the specific impulse of a fuel (ratio of thrust to fuel mass flow rate) in "seconds":— lb per lb/sec ≡ sec? One must be very careful not to fall down on this and similar points when converting to the system of units one is using; even Mr. Helmer's "foolproof and painless" method gives the wrong answer then.

Finally, no matter which system of units one uses, if you understand it, *then stick to it,* and for your own sake don't let Mr. Helmer or myself persuade you to change, for it's certain that the "g" will get you if you do! !

J. B. HARGREAVE
English Electric Aviation Ltd

Fitting questions

SIR: We were very interested in the Survey published on Page 114 of the November, 1960, issue of your magazine. We would like to query the dimensions given under the heading of the second column, namely, Approximate space required on Panel in Inches. You have shown for the Electroflo Model 199 a space of 8" × 8". Actually, the 8" is the minimum distance between the centre lines that the instruments should be mounted. You will note the incongruousness of some of the values you have shown under the first column as compared with the second column where, for instance, under the Electro Methods Recorder, the panel cut out 6½" × 3⅛" is the same as the approximate space required on the panel, viz. 6½" × 3⅛" which means, in effect, the instrument would have no bezel and would fall out backwards. Another instrument with which we are familiar is the Swartwout Recorder, where you have given 5" × 5" for the panel cut out (this is correct), but you have given 7" × 7½" as the approximate space on the panel. Actually, these are the minimum mounting distances between centre lines, namely, 7" horizontal and 7½" vertical.

The same considerations apply to our Model 361 Recorder, shown in Section B. Perhaps you would care to check these dimensions with the various principals, since it does appear to show our recorder in a less favourable light against some of the others.

We find your magazine very informative and hope that you will keep up the good work.

J. R. MCALLISTER
Electroflo Meters, Australia

● *Mr Spencer's reply will be published next month.*—EDITOR

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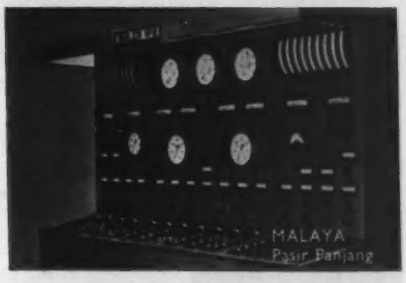

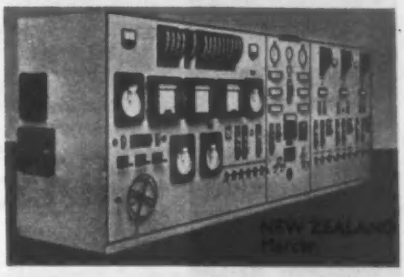

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VIEWPOINT

Sir Walter Puckey, Chairman of B.C.A.C. and Director of I.C.T., calls for the broader view, and says that control is . . .

MORE THAN ENGINEERING

Last year Professor Saunders said: 'it is becoming increasingly apparent that the natural process of making control more complex is proceeding at a faster rate than man's steps to simplify it'. This is no new phenomenon, as the early expansion of almost every new subject encourages complexity; it is only by strong deliberate attempts, often by non-specialists, that relative simplicity finally emerges.

What are the more obvious ways of simplifying this complex control field? Two in particular come to mind; both have as their objectives the development of common understanding by better and more frequent personal contacts between separate specialist groups and individuals.

The first requirement I have in mind is to establish, more firmly, a common understanding of the meaning and the objectives of control. Professor West in the January *Viewpoint* rightly said that control is 'the essence of engineering' rather than 'one subject', but even his own broad concept is narrow when one considers the wider definition, implication and usage of the word. It is only recently that scientists and engineers have taken 'control' under their wing, and created a highly complex mathematical, scientific, and technological tool. But let us remember that control is inherently a human word, involving control by one person, first of himself and then of other individuals or groups. It involves far more than engineering, and the more progress we make in technical control, the wider the gap we may create between it and the far more important, but as yet less intensively studied, human control. Let more of us therefore, as scientists, technologists and humanists (occasionally, but rarely, combined in one person), make even greater attempts to appreciate this broader base as a jumping-off ground for our own specialist activities.

This brings us logically to my second requirement, which is to create better organizations and machinery for maintaining this broader base, and making progress along a wider front. Two specific tasks emerge here. First, to create better communication and understanding among technical specialists, and secondly, to ensure that a fuller understanding is achieved between specialists and laymen, i.e., the general public, which is increasingly bewildered by modern technological developments.

The first task is to improve organizational means of co-ordinating more effectively the many and varied workers in this field. The more complex and subdivided 'control' becomes, the more important is the managerial task of organizing all concerned for the achievement of a common goal. The theory and practice of organization lag seriously behind many technologies.

The second task is one on which we have recently made some progress. The British Conference on Automation and Computation — B.C.A.C. — has been organized as a consortium of 32 of the major professional and associated institutions in the fields of automation and computation. It is concerned not only with technological, but with the economic and sociological aspects of these important subjects, and our hope is that it will provide not only greater opportunities for specialist professional bodies and their members to meet more frequently on common ground, but will ensure that society generally is more aware, in the simplest terms, of the economic and social possibilities that are presumed to emerge from better technical developments in, for instance, control.

Although myself a technologist by training, I believe that the next few years must demand a proportionately greater attention to the economic and sociological implications of words like *automation*, *control* and *computation*. As one contribution towards this, several member bodies of B.C.A.C. have organized what is the first British major conference on these matters. It will take place in Harrogate between 27 and 30 June this year, and its organizers hope that it will show to a wider public, not only that Britain can demonstrate her scientific and technological competence in these important fields, but that the Second Industrial Revolution is designed not by and for technologists only, but for the benefit of all.

Walter Puckey.

PART 1

After examining how a modern power station is run, the author shows what a computer can do to take over the routine work and give operators time to use their intelligence

Operating a power station with a computer

by **A. J. WAKEFIELD** B.A., D.Phil.
Panellit Ltd

THE MODERN ELECTRICITY-GENERATING SET IS A SELF-contained unit comprising a boiler, turbine and alternator, together with their many auxiliaries such as fans, pumps and, in coal-fired sets, pulverized fuel ('p.f.') mills. Instrumentation is extremely important in the achievement of both safety and minimum running cost. The number of quantities which are significant either for monitoring, corrective action or calculation is quite large. In addition, there are many on/off and yes/no indications. An example is the indication that a safety circuit has tripped an auxiliary, or that a valve is either fully open or fully closed. The plant operator is presented with such a mass of information that as the size of plant increases it becomes more difficult for him to operate the plant most safely and efficiently.

The object of a computer is to take over as much routine work as possible. The operator can then devote himself to obtaining the best performance from the plant. Eventually the system might monitor and reset the main control loops, the computer giving control demands to keep performance optimal.

Two examples will serve to illustrate what the operator is required to do. The first is his task when the generator is on full load—to produce the demanded power with least fuel consumption. However, the operator cannot read efficiency as simply as temperature on a meter. He would have to make several readings and perform a complex calculation upon them. In doing so he would take a considerable time, and the conditions of working might change so that the results no longer applied. The second example relates particularly to sets with two-shift working. In order to meet peak demands it is desirable that a set start in the shortest possible time after the demand for a load has been received. Time elapses both because the operator has a sequence of many operations to carry out, and because the boiler and turbine have to heat up to working conditions. This heating must occur at a rate which does not unduly stress the boiler and turbine by causing excessive differential temperatures. The maximum rate is prescribed by the turbine manufacturers, and should the operator wish to start up in the minimum time, he must allow the set to heat up as nearly to that maximum as possible. This involves accurate monitoring of the relevant temperatures to evaluate their rates of change.

The ideal generating set would be completely automatic when starting, when under load, and during shutdown. Under load it would operate as efficiently as possible. However, we shall discuss fully automatic operation here with reference to computing technique only, and not to equipment and instrumentation, some of which awaits further development.

MEASURING POINTS IN GENERATING SET

First, let us obtain some insight into instrumentation in a typical large set by looking at one section of the boiler—the path taken by feed-water during its conversion into steam at the appropriate pressure and temperature, namely 1500 lbf/in² and 1000°F. The water–steam path begins at the outlet of the last feed-pump, and consists of the economizer, the drum, and the radiant, primary, secondary and final superheaters. It ends at the superheater outlet. We may also consider the reheater here, since the used high-pressure steam takes up further energy for use in another turbine stage.

In the boiler there are numbers of local automatic controllers to maintain certain critical quantities at set values. These quantities are:

(*i*) Pressure at the superheater outlet
(*ii*) Temperature at the superheater outlet
(*iii*) Reheat temperature
(*iv*) Drum water level

With these set values, there is a certain temperature and pressure distribution along the path. The points where the temperature and pressure are of most interest are inlets and outlets of the various sections detailed above. The outlet of one section may be physically so near the inlet of the next section that it is not worth having two sets of instruments. Temperature differences between the inlet and outlet of the superheater sections are also measured. These differences are conveniently measured by thermocouples. Feed-water pressures and flows are measured in the drum and economizer. Automatic controllers have to be examined to check that the difference between the measured value and the controller's set point is small.

The following are some of the contingencies that should be detected, and followed by a shut-down, reduction in load, or some other corrective action:

1 Rupture or leakage of any high-pressure portion of the boiler or interconnecting pipes
2 Overheating of the superheating or reheating tubes
3 Excessive main-steam or reheated-steam temperature
4 Excessive rate of change of drum, superheater or reheater temperature
5 Excessively high or low water in the drum
6 Inadequate pressure in the feed-water heater

The method of detection will be direct or indirect according to the fault. Leakage will be indicated by an abnormal pressure and/or temperature distribution proportional to the seriousness of the fault. Deterioration or the deposit of solids will also be indicated by a change in the pattern of readings with time.

In normal operation the measurement of pressures and temperatures will assist both safe starting-up and efficient operation on load.

OTHER PORTIONS OF THE COMPLETE SET

Other portions of the set comprise the furnace, the pulverized fuel ('p.f.') mill, the condensate and feed-water sections, the turbine, the generator, and accompanying auxiliaries (such as fans and pumps). These will now be considered briefly.

The furnace includes the forced-draught ('f.d.') and induced-draught ('i.d.') fans, air heaters, p.f. and oil burners, the furnace chamber, the gas-recirculating-fan grit arresters and precipitators. The furnace chamber is divided into sections by dampers and ducts which correspond approximately to the sections in the steam-generating portion. Pressure differences across dampers indicate correctness of damper settings. Many possible alarm conditions can arise, such as a fan failure or burner-flame failure (p.f. or oil), or the appearance of combustibles in the flue gas owing to low 'excess' air.

In the turbine, lubricating-oil and bearing temperatures are important. The mechanical behaviour of the turbine is critical and indicated by the axial displacement and eccentricity of rotors, and also by pedestal movement and vibration, casing temperature, and turbine speed. In the generator, the temperatures of the rotor stator and the hydrogen cooler are very important.

Only the more critical measurements have been listed above. The total of measurements is large, and the installation of a computer can ensure their fullest use.

COMPUTER INPUT FROM PLANT

Measurement signals to the computer are in the form of direct voltages. Thermocouples give these directly, and other measurements call for transducers. Valves

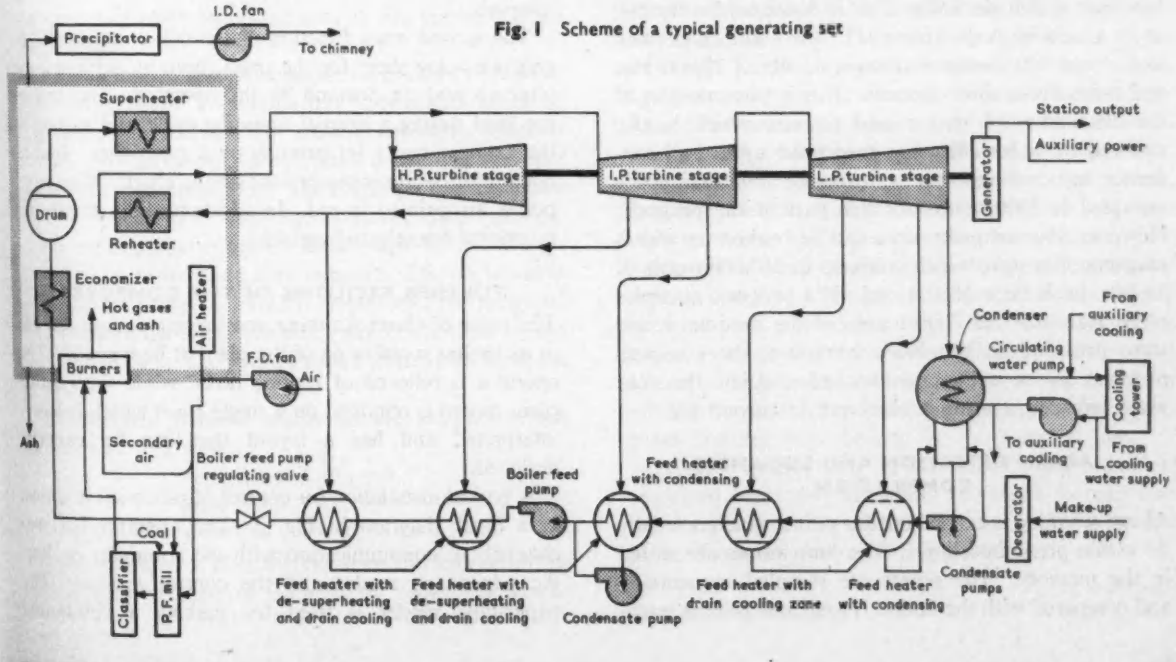

Fig. 1 Scheme of a typical generating set

which are either open or shut are fitted with electrical contacts whose closure indicates the position.

These direct voltages can be selected by a switch which is an array of relays. In the Panellit 609 system, mercury-wetted relays are used for reliability. The chosen signal is fed to a pre-amplifier, if necessary, and then to an analogue-to-digital converter ('a.d.c.') if the quantity is a measurement. If it is an on-off indication, the computer detects the presence or absence of a voltage.

In either case, the selected signal is produced in a form suitable for the computer. In a power station, there are important quantities not measurable as direct readings. For example, measurements of gas flow are made from a basic pressure P, a pressure-drop ΔP and a temperature measurement T. The flow is given by the formula $F = k(P.\ P/T)^{\frac{1}{2}}$. The 609, being a general-purpose computer, can perform the multiplication, division and square-rooting involved; so flows are obtained by measuring the basic quantities and computing rather than by feeding them into an external analogue device and noting its output.

Rate of change or mean values of temperature can be computed as a by-product of temperature measurement, since previous information can be retained in the computer's store or 'memory'. Calibration, which is necessary when a measured value is a non-linear function of the output of an instrument or transducer, is done by computation on the basic input.

Another mathematical process which is required in measurement is integration. To determine the total flow of feed-water, steam, or condenser cooling water during an hour, shift or day, the flow is sampled at definite time intervals and summed over the period. The computer's ability to derive fuller information from the input data is provided by calculation of the gross turbine heat rate in Btu per kWh. This is discussed for the 609 in an article by A. F. Sperry (*1*). The entire calculation uses about 700 words of storage, i.e. about 27,000 bits, and takes about three seconds. This is just one part of the calculation of station performance, which is also assessed by boiler efficiency, feed-water cycle, and condenser and cooling-tower performance. The total space occupied is 3000 words for this part of the program. However, the computer store can be backed up with a magnetic-film store which holds up to 260,000 words of 39 bits, each on a 1000 ft reel. If a program occupies more than 4000 or 8000 words of the random access store provided in the basic computer, the complete program can be written on film and read into the store when required, erasing a block not in current use.

ALARM DETECTION AND LOG-SHEET COMPILATION

Alarm scanning is carried out for points which normally lie within prescribed limits. The limit values are stored in the memory. The points are sampled sequentially and compared with the limits. Visual and audible warning is given when an abnormal value is detected. A record of the alarm is printed in red, and on return to normal a further print is made in black.

For alarm indications points are divided into groups of one or more. The standard Panalarm display contains a number of red and green lights for alarm and normal indication of groups of points. When any point in a group goes into 'alarm', the appropriate green light is extinguished and a red one flashes on, the common alarm bell rings, and a print is given in red on the strip printer. The alarm is then acknowledged by the plant operator, the bell is silenced, and the red light becomes steady. If another point in that group goes into 'alarm', the bell again rings, there is a print-out, and the red light starts to flash again. Thus each new alarm point has to be acknowledged. When all points in a group have returned to normal (accompanied by black print-outs on the strip printer) the red light goes out and the green one comes on.

If there is a transient alarm of a point or points, which is not acknowledged by the operator until after it has returned to normal, then a complete printed record is made as before, but the flashing red light returns directly to a steady green one when the 'acknowledge' button is pressed; in this way no transient alarm can escape attention.

In a typical generating set, there will be 300 to 600 points. The 609 computer selects these in turn at a rate of five a second, and the complete sampling cycle takes from one to two minutes. More critical points can be sampled more frequently, because the sequence of sampling is stored in the computer's memory and not determined by built-in equipment. The beginning of the cycle is synchronized to a pulse from a digital clock. This is important when rates of change or integrals have to be calculated, since points must be sampled at fixed intervals.

The second main function of the 609 computer is to produce a log sheet for the plant, both at definite time intervals and on demand by the operator. The values are read during a normal scanning cycle and stored in the memory ready for printing on a typewriter. Identifying information is pre-printed on the chart. Off-normal points are printed in red. In addition, daily totals can be printed for selected variables.

FURTHER FACILITIES OF THE COMPUTER

The value of alarm scanning and logging equipment lies in its tireless monitoring of the plant at high speed. The operator is relieved of routine tasks, while the routine plant record is obtained on a single chart which is easily interpreted and has a layout that can be expertly designed.

A typical installation for control of processes is shown as a block diagram in Fig. 2. The operator has two channels of communication with the computer on line, the paper-tape reader and the control console. The paper-tape reader is used for making a substantial

change to data stored in the memory. For example, if a group of alarm limits needs to be changed, the point reference and value of the limit is punched for each point. The operator then places the tape in the reader and presses a key. Thus alarm levels can be changed with ease; while the tape is being dealt with, scanning continues at the normal rate.

The control console is useful for altering single pieces of data in the memory and for interrogating the system. The types of interrogation command which can be issued include read-out of the value or item of stored data of a single point or a summary of a group of points; also the elimination of a point from scan or print in the log sheet. The operator can also demand a log or summary of all points currently abnormal.

In order to prevent unauthorized alteration of information in the computer's memory a locked switch is provided which prevents alterations when turned to the off position.

Before considering extensions of the use of a 609 computer, the physical layout will be considered in greater detail.

THE 609 SYSTEM

The centre of every 609 computer is a standard 803 general-purpose computer. The normal peripheral equipment of an 803 consists of a tape reader for input and tape punch for output. These have their own channels for input and output. In addition the 803 has spare channels, one for input and one for output; these are used for all transfers of information between the additional 609 peripheral equipment and the central computer. The machine can be used purely as a general-purpose computer when off line.

The special unit comprising the 609 can be divided into three sections indicating their purpose; input, output, or time-sharing. Input and output can be subdivided into plant input and output and operator input and output.

Process inputs were discussed earlier, under *Computer input from plant*. To summarize: they consist of on-off indications or readings, they are read through a selection switch and an analogue-to-digital converter, and five points are read per second. The converter has resolution of 1 in 4000. Up to a thousand inputs can be specified.

Operator inputs comprise three main devices; a keyboard, tape reader, and control panel. The keyboard is used when testing or initially 'inputting' the program. The tape-reader's use on line was considered in the previous section, and it is also used initially to input the program.

The control panel contains decade switches which specify the following:

Point number	0 to 999
Point value	0 to 9999
Command	0 to 99

The command is the function to be carried out on the stored data or type of information requested by the

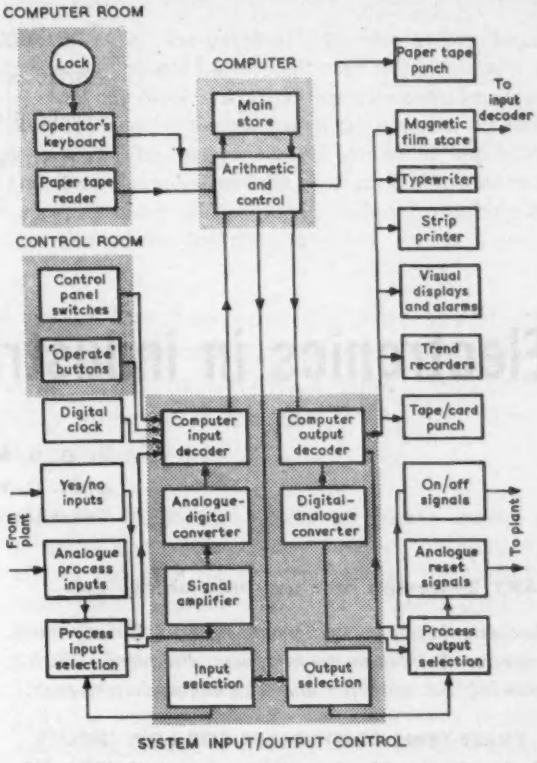

Fig. 2 Block diagram of 609 system for process control

operator. The set of commands is not rigidly specified, but decided for each application as it arises. A list of commands is prepared, and numbers in the range 0 to 99 are allocated. A command is then specified by its code number. In most cases, the decade switch positions are engraved descriptively.

Process outputs have been studied. The method of selection of an output point will be by a relay matrix as for input. These will provide the link between the computer and the 609 for applications where it is controlling a plant without manual intervention.

Outputs for the operator comprise printing devices, tape and card punches, visual display and alarm indications. Permanent recording of information follows a similar pattern, whether the device used is a typewriter, adding-machine printer, tape punch or card punch. Basically, the computer can send information one character at a time until the item has been output. The typewriter is very useful for printing a log, as the carriage can hold a pre-printed chart accurately aligned by means of a sprocket feed. The adding-machine printer is more useful for alarm printing and operator demands. Tape and card punches are more useful for printing analyses or recording information for subsequent printing or processing by computer off line.

Visual displays using in-line decimal indicators are employed when they are more convenient to read than typed figures, or for automatic output of the current value of some rapidly changing quantity.

To be continued

The second part of this up-to-date review ends with a description of three-term controllers for low inputs and standard transmission signals

Electronics in industrial process control

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PART 2—Design of electronic units—*cont'd*

The main headings last month were: A.C.-ratio-to-d.c. converter, Solid-state servo-system, Frequency sharing, Low-drift d.c. amplifier and Thermocouple converter.

THREE-TERM CONTROLLER FOR LOW INPUTS

The low levels of both voltage and current drift of the amplifier enable one to use it as a controller providing a 0–10mA proportional, integral and derivative output from a thermocouple or other millivolt input (Fig. 16). For this application the cold-junction compensation circuit is similar to that used in the thermocouple con-

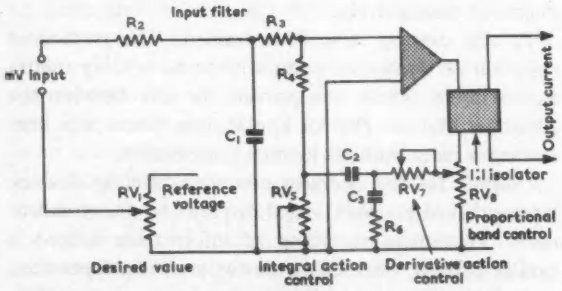

Fig. 16 Use of d.c. amplifier as three-term controller for low-level inputs

converter, but the input signal is compared with a voltage representing the desired value and set by the potentiometer RV_1.

The input filter resistance is chosen to produce a maximum input current of a few hundred times the amplifier current drift. This input current is opposed by that fed back from the integrating networks *via* R_4. Thus the system operates by balancing currents rather than voltages.

With the derivative resistor set at zero, a step change in the input voltage will cause an immediate proportional step in the output, whose value depends on the setting of the proportional band control. The integrating capacitor C_2 will then discharge slowly through R_4 and RV_5. The discharge current will steadily decrease as the voltage across R_4 falls, and if the input deviation persists, the controller output will continue to increase at a rate depending on the integral action time.

The response at higher frequencies is determined by the values of R_6, RV_7 and C_3. As the input frequency increases the impedance of C_3 falls, less current is therefore fed back, and the controller output increases. The derivative gain is limited by R_6 to a value of $(R_6 + R_7)/R_6$, for at very high frequencies the impedance of C is negligible and the feedback is then attenuated by $R_6/(R_6 + R_7)$.

THREE-TERM CONTROLLER FOR 10mA INPUTS

When the input to the controller is the standard transmission signal of 0 to 10mA from a signal converter, the deviation signal θ may conveniently be several volts. The low voltage-drift of the amplifier then enables one to place the derivative network in the feedforward path as shown in Fig. 17.

Assuming that the input signal is arranged to drop 0 to 5V across R_1 (a level convenient for comparison with a desired value derived from a Zener diode), then a proportional attenuation of about 1000 will still leave a signal across R_4 which is large compared with the

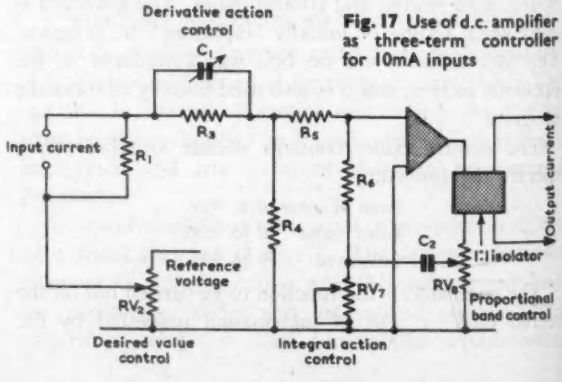

Fig. 17 Use of d.c. amplifier as three-term controller for 10mA inputs

voltage drift. The derivative gain of the circuit may therefore be very high, allowing a long derivative action time R_3C_1, but a short time constant for R_4C_1, and thus providing rapid recovery from input transients, changes in set point etc.

Placing the derivative network outside the feedback loop of the amplifier confers a further important advantage. While the regulator is being operated by a manual signal, the potential difference across the integrating capacitor may be adjusted either manually or by some automatic system, so that the controller output is always equal to the manual signal, whatever the input deviation. This makes integral saturation impossible, and allows bumpless transfer from manual to automatic operation under all conditions, without disturbing the operation of the derivative networks.

PART 3—Operation of regulators

Final regulation of an industrial process requires mechanical movement, induced electrically, pneumatically or hydraulically. Electronic circuitry may be associated with the various kinds of actuator

THE TWO PREVIOUS PARTS OF THIS ARTICLE HAVE DEALT largely with those units of a process control system which have electrical inputs and outputs. Except in the case of an electric furnace, however, final regulation of an industrial process is generally by some mechanical means, such as a valve or damper. A range of devices must therefore be provided to convert electrical signals into mechanical movements of suitable thrust and stroke. The operation of such actuators may be electric, pneumatic or hydraulic, although a novel actuator based on the pressure exerted by an electrically evaporated fluid has recently been described (7). In the following sections we shall deal with the electronic circuitry used in conjunction with these types of actuator.

ELECTRICAL ACTUATOR

The use of an all-electric actuator appears attractive for a number of reasons. It eliminates the need for a compressed-air supply or oil pump, and allows the final actuating signal to be carried along normal electric cables. In the smallest actuators it may be possible to use a non-rotary motive device such as a torque motor, exerting a torque of a few pound-inches but moving through an angle of only a few degrees. Nevertheless, for the majority of applications the required mechanical power and stroke necessitate a normal rotating electric motor and gear-box.

The purpose is to drive the final regulating device to a position representing the output of a control unit such as described in the previous part of this article. This implies the use of a servo-system in which the speed and direction of the electric motor are controlled by an amplifier which continually compares the regulator position with the controller output. To avoid continuous hunting of this regulator control loop the amplifier must be able to control smoothly the power supplied to the motor, and have facilities for phase advance if required. If the amplifier is to be based on solid-state circuit elements then a motor of up to about 1hp may conveniently be used, as this power may be handled economically either by transductors or silicon controlled rectifiers. Motors of higher power are generally three-phase types, controlled by contactors, and in this case the amplifier driving the contactors must have a gap or dead band to avoid continuous hunting. The performance of such a system is limited by this dead band, which must be broadened as the actuator speed is increased. A small actuator, with a full-scale response-time of one minute, may require a dead band of one or two per cent, and the contactor-controlled type of actuator is therefore unsuitable where maximum speed and sensitivity are required.

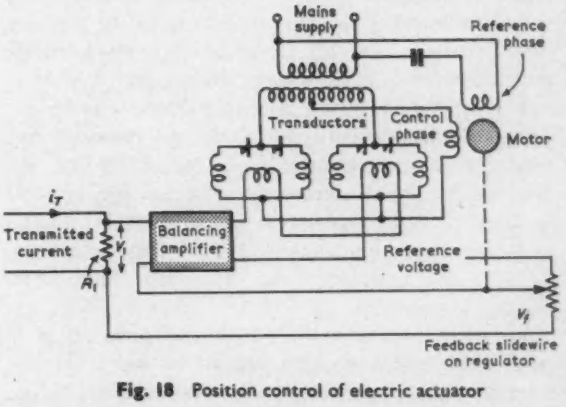

Fig. 18 Position control of electric actuator

A solid-state control system suitable for a small electric actuator is illustrated in Fig. 18.

The actuator itself is a gear-box driven by a two-phase induction motor. The reference phase is supplied direct from the mains supply, *via* a suitable capacitor, and the control phase is arranged in a bridge circuit with two self-excited transductors. The current transmitted from the controller is passed through resistor R_1 to develop an input voltage V_1, which is balanced against a position-feedback signal V_f, obtained from a potentiometer attached to the actuator. Any difference between V_1 and V_f is fed to a directly coupled transistor amplifier. The output current from this amplifier passes through the control windings of both transductors, but in opposite phase. The transductor

bias current may be adjusted so that, when $V_1 = V_f$, both transductors give minimum output. Any change in the input current will now increase the output from one or the other transductor, supplying either in- or anti-phase current to the motor, and driving the gearbox to balance.

HYDRAULIC ACTUATORS

Hydraulic actuators have been used successfully for several years in the aircraft and similar industries, but to a much smaller extent in the industrial process control field. The main reason for this has been the wide-spread use of air as the operating and transmission medium in process control systems. With the advent of electronic control the hydraulic actuator may be considered on its own merits, and is likely to find wider use during the next few years.

The circuitry associated with such actuators depends mainly on whether or not the unit contains its own position-feedback loop. To be compatible with the d.c. transmission system described earlier, the actuator should accept a small d.c. signal and position the load accordingly. The comparison of position with input current is performed most simply by a force-balance system. The input current is passed through a coil in the field of a permanent magnet, and the force so produced is balanced against the bending moment on a spring deflected by the final movement of the actuator. Any unbalance operates valves which apply hydraulic pressure either to raise or lower the actuator.

This type of actuator is relatively simple, may be self-contained (including its own pump and reservoir) and need contain no electrical parts except for the coil carrying the input current. A disadvantage in some applications is the fact that failure of the current input or power supply to the motor may cause the actuator to move to one end, and it may then be difficult to reposition it manually.

An alternative system for hydraulic actuators is to control the direction of movement by means of two solenoid valves, and use an electrical feedback and balancing system. This method is identical in principle with that described for the electrical actuator in the previous section, and the amplifier must have a gap or dead band so that both valves are closed when the actuator is in its balanced position. If the electric supply fails, both valves remain closed, but they may be operated manually if required. This type of system is not normally self-contained, and finds application where a central hydraulic pump and reservoir feed a number of positioning rams.

PNEUMATIC ACTUATORS

Pneumatic actuators, such as diaphragm valves and power cylinders, retain considerable advantages, particularly in the oil and chemical industries, in view of their power-storage capacity, speed of response, and safety. Normally these actuators position a regulating unit to correspond with a 3 to 15 lbf/in^2 air pressure. They may thus be used in conjunction with an electrical transmission system by incorporating an electropneumatic converter which changes the standard electric transmission current into a directly proportional air signal. In the case of a power cylinder, a mechanical/pneumatic position-feedback loop is then included in the actuator itself.

The electropneumatic converter, and any remaining pneumatic transmission lag, may be eliminated if the transmission current and regulator position are balanced in the actuator. This may be done, as in the hydraulic case, by passing the transmission current through a coil in a magnetic field, and balancing the resultant force against that fed back *via* a spring from the regulator movement. Any unbalance is used to control the movement of the piston by applying air pressure to one side or the other in the usual manner. Such a system retains many advantages of both electronic and pneumatic control. The power and speed of response possible using compressed air are retained, whilst transmission lags are eliminated.

The actuator may easily be made intrinsically safe, and if the electronic units are designed for battery operation, temporary control can be maintained if the mains supply fails.

INCLUSION OF CONTROLLER IN FEEDBACK LOOP

In the systems described above, the transmission current from the controller to the actuator defines the position, rather than the direction or speed of travel, of the regulator. The feedback round the controller contains the proportional and integral networks, while a separate position-feedback loop is closed round the actuator and its balancing amplifier. Where an electric or hydraulic actuator is used with an electronic position-control loop, the position feedback is an electrical signal which should reproduce exactly the output signal of the controller (Fig. 19). Provided that each controller feeds only one actuator, the position-feedback signal may alternatively be applied directly to the proportional and integral network of the controller, thus eliminating the need for a balancing amplifier (Fig. 20). The output signal of the controller amplifier now determines only the speed and direction of the actuator,

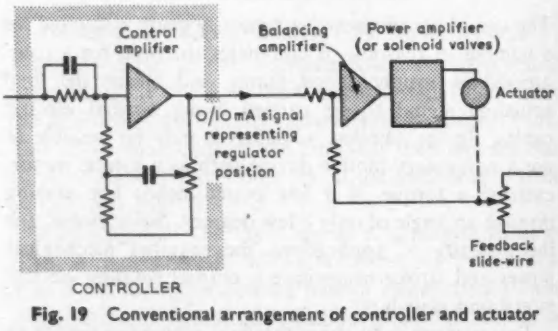

Fig. 19 Conventional arrangement of controller and actuator

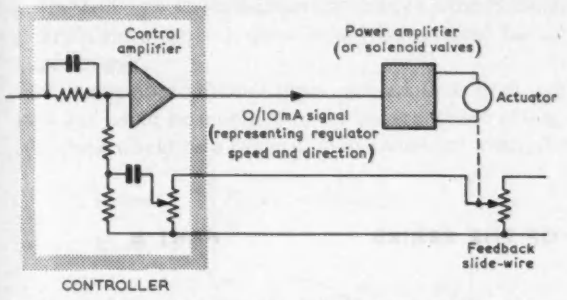

Fig. 20 Inclusion of controller in feedback loop of regulator

and operates either a power amplifier (for an electric actuator) or a pair of solenoid valves (for the hydraulic actuator).

TRANSFER FROM MANUAL TO AUTOMATIC OPERATION

A major problem in the operation of three-term controllers is in the transfer from manual to automatic operation and *vice versa*. While the regulator is being operated manually the controller is disconnected from it, and the controller output will generally increase slowly during this period owing to integral action, until the controller amplifier saturates. If the process is now transferred to automatic operation, the regulator will be moved rapidly to one end of its travel, putting a possibly dangerous bump into the process.

In many controllers this possibility is overcome by having a 'balance' position on the 'auto.'/'manual' switch. By switching to this position the operator can compare on a balance meter the controller's output signal with the manual signal being fed to the regulator. By adjusting the set point on the controller, these two signals may be equalized, and transfer to automatic control is bump-free.

The necessity for moving the set point in order to balance the outputs is clearly undesirable, since the operator must remember subsequently to move it back to its correct value, and this correction, if done too quickly, can itself put a bump into the process.

Indeed, it is undesirable for the operator to have to do any balancing at all, for it may cause delay and confusion in a complex process. This may be avoided by an automatic system, which continuously adjusts the controller output, while it is being manually operated,

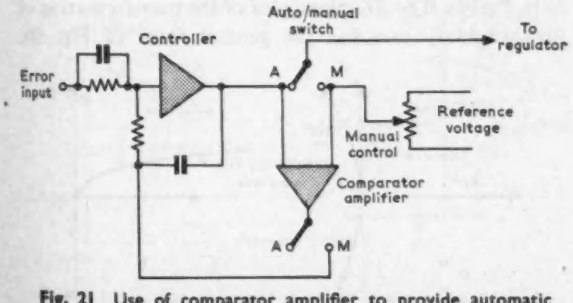

Fig. 21 Use of comparator amplifier to provide automatic bumpless transfer from manual to automatic operation

to equal the manual control signal. A bumpless change may then be made from 'manual' to 'auto.' by one switching operation.

A suitable arrangement is shown in Fig. 21. This is applicable to systems in which the output current represents the regulator position. A subsidiary comparator amplifier continuously compares the controller and manual outputs. While operation is manual the output of this amplifier is connected to the integrating capacitor of the controller, whose potential is then continually adjusted so that the controller and manual outputs are equal, permitting a simple, bumpless transfer from 'manual' to 'auto.' whatever the value of the deviation θ. To transfer the process back to manual operation, the operator must make the manual control setting correspond with the indicated output current before switching over. This balancing action could alternatively be performed by an electromechanical positional servo-mechanism which continuously adjusts the manual control.

If the controller and actuator are both included in the same feedback loop, as described in the previous section, then the controller output does not represent the regulator position, but determines its speed and direction of movement. Then, as shown in Fig. 22, the

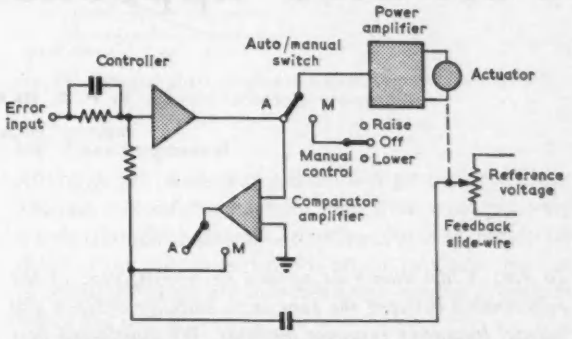

Fig. 22 System providing automatic bumpless transfer in both directions

comparator amplifier must be arranged to adjust the output of the controller to zero while on manual control, so that, when a transfer to automatic control is made, the regulator remains steady, since the power to the electric actuator (or solenoid valves) is zero.

In this system, if manual operation of the regulator is performed by 'raise' and 'lower' push-buttons or switches, rather than by a variable voltage or current source, the transfer from 'auto.' to 'manual' is also bumpless under all conditions, for as soon as the switch is in the 'manual' position, the power to the regulator is cut off until one of the push-buttons is pressed.

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Acknowledgements

Acknowledgement is due to Messrs D. Summers, D. N. Harrison and L. C. Towle, who have played an important part in developing some of the equipment described.

The directors of George Kent Ltd are thanked for giving permission for the article to be published.

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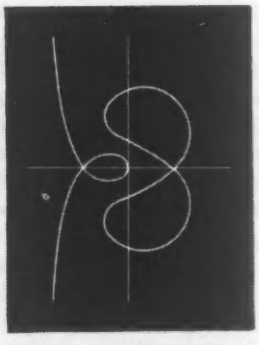

NUMBER FIVE OF THE SERIES PART B

How the root-locus stability criterion compares with stability standards based on the usual frequency response methods

Pole-zero approach to system analysis

by **P. F. BLACKMAN**
Imperial College of Science and Technology

In Part A last month we opened an investigation of the relationship between the root locus stability criteron and normal frequency response methods. We considered first a system with three poles.

Higher-order systems

For the case of a system with a larger number of poles, two 180° lines might cross the imaginary axis in the p-plane at ω_1, ω_3, with a 0° line between them at ω_2 in Fig. 8a. For such a situation, the constant-magnitude line through ω_1 would cut the other 180° line in the left half plane, so that as the gain increased the closed-loop system would become unstable at the lower frequency

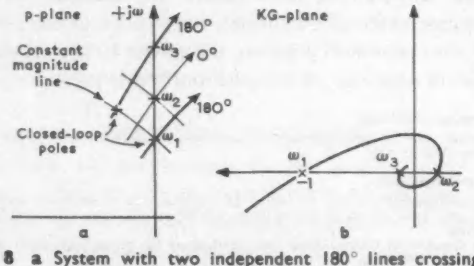

Fig. 8 **a** System with two independent 180° lines crossing the imaginary axis, with closed-loop pole at ω_1
b Corresponding KG-plane plot

ω_1 when the first pole reached the imaginary axis. In the KG-plane the transformed imaginary axis would have the shape of Fig. 8b.

Conditional stability and instability

For a system with an open-loop transfer containing a second-order pole at the origin and an additional pole on the negative real axis

$$KG(p) = K_1/p^2(p\tau_1 + 1)$$

there will be two entire 180° lines in the right half plane as in Fig. 9a. The KG-plane plot of the transformation of the imaginary axis has the general form of Fig. 9b,

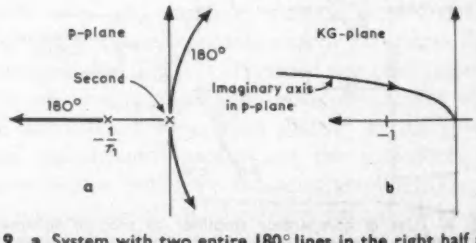

Fig. 9 **a** System with two entire 180° lines in the right half plane
b Corresponding frequency-response plot in KG-plane

corresponding with permanent instability by the Nyquist criterion since the -1 point would be enclosed for all values of gain.

If, owing to additional poles and zeros in $G(p)$, the 180° line could be modified to the general shape of Fig. 10a, there would be a range of gain values for which the

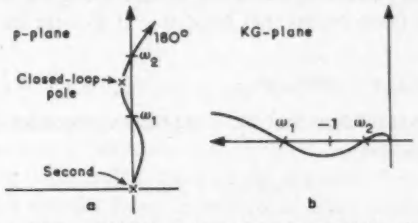

Fig. 10 a Shape of 180° line in p-plane for conditional stability
b Corresponding frequency-response plot in KG-plane

closed-loop system would be stable, with poles occurring between ω_1 and ω_2. This gives a *conditionally stable* system, and Fig. 10b shows the transformation of the imaginary axis into the KG-plane. Alteration of gain causes the size of the plot to change, giving instability at ω_1 or ω_2.

A system in which a 180° line loops over the imaginary axis and returns to the left half plane as in Fig. 11, where the line might terminate on a zero, will give a *conditionally unstable* system.

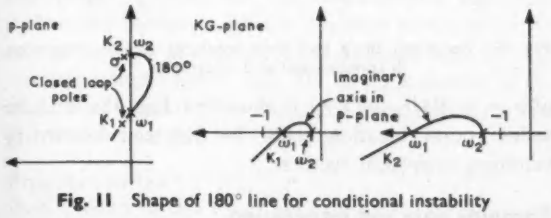

Fig. 11 Shape of 180° line for conditional instability

Bode diagrams

If Bode diagrams are used for stability determination, the criteria of *phase* and *gain* margins are employed (*4*), these being relevant to the frequency response conditions when the forward-path gain has fallen to unity and the forward-path phase-shift reached 180°.

As applied to a system with an integration and a single time constant in the forward path $KG(p) = K_1/p(p\tau_1 + 1)$, the diagrams would be as in Fig. 12a, if a phase margin of 40° is used to define the 0 dB line of the open-loop transfer. In the p-plane this means that the gain value is

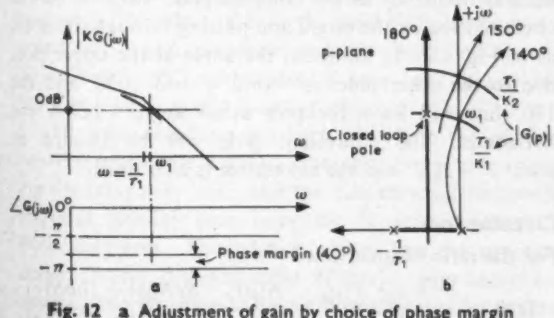

Fig. 12 a Adjustment of gain by choice of phase margin
b Root-locus representation of a

adjusted so that the constant magnitude line

$$|KG(p)| = 1 \quad \text{or} \quad |G(p)| = \tau_1/K_1$$

passes through the point on the imaginary axis where the open-loop 140° phase line cuts the axis. The closed-loop pole will be located where this line cuts the 180° line, as in Fig. 12b. If the phase margin is reduced to (say) 30° the gain can be increased to K_2, and the constant-magnitude line $|G(p)| = \tau_1/K_2$ determines the closed-loop pole but will lead to a reduced α/ω ratio and an inadequately damped transient response.

For a more complicated system with two time constants in the forward path, both gain and phase margins can be considered. The gain margin indicates the reduction in magnitude where the 180° line crosses the imaginary axis in Fig. 13.

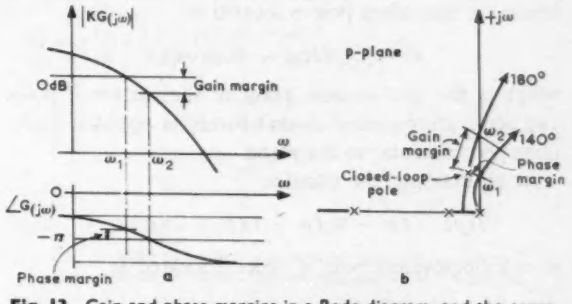

Fig. 13 Gain and phase margins in a Bode diagram, and the corresponding root-locus representation

180° lines in general

Although 180° lines play a dominant part in root locus analysis, it is unfortunate that, apart from some relatively simple (though commonly occurring) patterns, the actual detail of the 180° lines depends on the particular pattern in question. There are however some general properties which are useful.

Asymptotes and equivalent pole

For functions of the general form

$$T(p) = (p^n + a_1p^{(n-1)} \ldots)/(p^{n+r} + b_1p^{(n+r-1)} + \ldots)$$

the behaviour for large values of p is closely approximated by

$$T(p) = 1/p^r$$

Assuming that r is positive this approximation corresponds to an *equivalent* pole of order r at the origin, and there will be r 180° lines in the plane spaced at angles $2\pi/r$ as in Fig. 14a, for $r = 3$. Although to a first approximation the equivalent pole is located at the origin, it is sometimes useful to develop a slightly closer approximation, and it can be shown* that for large values of p

$$T(p) \simeq 1/[p + (b_1 - a_1)/r]^r$$

* see Appendix A.

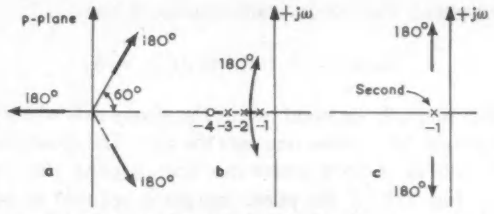

Fig. 14 **a** Simple approximation, by a third-order pole at the origin to a function where (poles − zeros) = 3
b More exact approximation where (poles − zeros) = 2

indicating that a better approximation is a pole of order r at

$$p = (a_1 - b_1)/r$$

and the coefficients a_1, b_1, may be identified as

$$b_1 = -\Sigma(\text{poles}), \quad a_1 = -\Sigma(\text{zeros})$$

hence the equivalent pole is located at

$$p = [\Sigma(\text{poles}) - \Sigma(\text{zeros})]/r$$

which is the *zero moment* point of the pattern if poles and zeros are regarded as unit forces in opposite directions perpendicular to the plane.

As an example, the transfer

$$T(p) = (p + 4)/(p + 1)(p + 2)(p + 3)$$

gives an equivalent pole of order 2 located at

$$p = (-6 + 4)/2 = -1,$$

and Fig. 14b gives the asymptotic 180° lines.

Saddle points

For a function

$$T(p) = \frac{(p - p_a)(p - p_b)\ldots}{(p - p_1)(p - p_2)\ldots}$$

saddle points occur where

$$\frac{dT(p)}{dp} = 0$$

and it can be shown* that this corresponds with the condition that

$$\frac{1}{(p - p_1)} + \frac{1}{(p - p_2)} + \ldots = \frac{1}{(p - p_a)} + \frac{1}{(p - p_b)} + \ldots \; (= 0 \text{ if no zeros})$$

indicating that saddle points occur for values of p for which the sum of reciprocal vectors to poles and zeros are equal. This relation is sometimes useful to estimate the position of a saddle point on the real axis, but is rather more tedious to interpret at general points in the plane.

In addition to the results obtained for equivalent poles and saddle points, some of the simple common patterns have certain geometrical properties which are useful.

* see Appendix B.

Two time constants and integration

A function of the form

$$G(p) = 1/p(p\tau_1 + 1)(p\tau_2 + 1) = ReG(p) + jImG(p)$$

where *Re*, *Im*, represent the real and imaginary components of the function, will give a 180° line crossing the imaginary axis at a frequency ω_1, and along the 180° line the condition occurs that $ImG(p) = 0$. For the frequency ω_1

$$G(j\omega_1) = 1/[(j\omega_1)^3\tau_1\tau_2 + (j\omega_1)^2(\tau_1 + \tau_2) + j\omega_1]$$

and the condition that the imaginary component be zero requires that

$$(j\omega_1)^3\tau_1\tau_2 + j\omega_1 = 0$$

giving

$$\omega_1 = \pm 1/\sqrt{(\tau_1\tau_2)}, \text{ and also } \omega_1 = 0$$

the zero solution being due to the limiting condition at the origin. The final asymptote from the equivalent pole

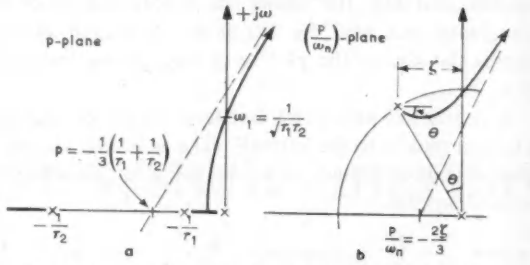

Fig. 15 Geometry of: **a** two time constants and an integration, **b** complex pair and integration

at $p = -\frac{1}{3}(1/\tau_1 + 1/\tau_2)$ is shown in Fig. 15a, and the saddle point location could be obtained exactly by summing reciprocal vectors.

Complex pair and integration

The corresponding function has the form

$$G(p/\omega_n) = 1/\{(p/\omega_n)[(p/\omega_n)^2 + 2\zeta(p/\omega_n) + 1]\}$$

and when the 180° line crosses the imaginary axis at a frequency ω_1/ω_n, the condition again occurs that

$$ImG(j\omega_1/\omega_n) = 0$$

which requires

$$(j\omega_1/\omega_n)^3 + (j\omega_1/\omega_n) = 0$$

or

$$\omega_1 = \omega_n$$

showing that the 180° line crosses at the undamped natural frequency of the complex pair, which is on the circle centred on the origin and passing through the poles as in Fig. 15b. In addition, the angle at the upper pole due to the other poles is $-(\pi/2 + \pi/2 + \theta)$, and the 180° line will leave the pole at an angle θ below the horizontal. The equivalent pole will be located at $p/\omega_n = -2\zeta/3$, and the asymptote is also shown.

Circular loci

For the ratio of quadratics

$$T(p) = \frac{p^2 + a_1p + a_0}{p^2 + b_1p + b_0} = \frac{N(p)}{D(p)} = \frac{ReN(p) + jImN(p)}{ReD(p) + jImD(p)}$$

the 0° or 180° locus is given by the condition $ImT(p) = 0$, and if the expression for $T(p)$ in real and imaginary components is rationalized the condition leads to

$$ImN(p) \times ReD(p) - ImD(p) \times ReN(p) = 0$$

If $p = \alpha + j\omega$ is substituted the final condition obtained is

$$\omega[\omega^2(b_1 - a_1) + \alpha^2(b_1 - a_1) + 2\alpha(b_0 - a_0) + a_1b_0 - a_0b_1] = 0$$

which yields one result, $\omega = 0$, corresponding to the entire real axis, while the second term is the form of the equation for a circle centred on the real axis. Hence there will be a circular locus composed of some combination of 0° and 180° lines. Some examples are given in Fig. 16.

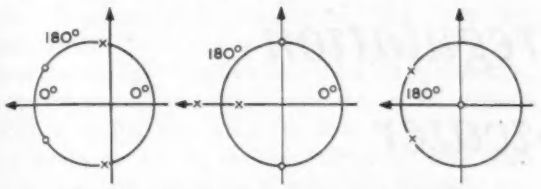

Fig. 16 Circular loci arising from quadratic ratios

If all the poles and zeros are complex, the locus is immediately defined as the only circle passing through all four points. If there are real and complex pairs, the circle must pass through the complex pair and it will cut the real axis at a saddle point. If either $N(p)$ or $D(p)$ contains a single factor only, the circle is centred at the single factor, but if poles and zeros alternate on the real axis, circular loci are not obtained.

Progress so far

Parts 4 and 5 of this series have shown the development of complex frequency ideas into the root-locus method for closed-loop system analysis. The endeavour has been to illustrate how in the root-locus method situations may be considered as pole-zero patterns with attendant properties, such as 180° lines, which immediately present information of considerable significance graphically with the minimum need for detailed analysis. Also latterly some properties of patterns have been developed which are useful in general applications.

From the root-locus method it is possible to see qualitative explanations of results familiar from Bode diagrams, such a magnitude changing inversely with frequency (the effect of a single pole) will also be associated with a limiting phase angle of $-\pi/2$, and changing inversely with the square of frequency (a second-order pole) will give a limiting angle of $-\pi$.

Also some emphasis has been placed on the relation between root-locus stability, determined by a pole crossing the imaginary axis, and the conventional frequency response stability tests using the Nyquist criterion or Bode diagrams. The relation shows that the practical design criteria, damping ratio, M-circles, gain and phase margins, merely serve to locate closed-loop poles an adequate distance from the imaginary axis in the p-plane.

APPENDIX A

Equivalent pole

If a ratio of polynomials $T(p)$ is divided out the following is obtained

$$T(p) = \frac{p^n + a_1p^{(n-1)} + a_2p^{(n-2)} + \dots}{p^{(n+r)} + b_1p^{(n+r-1)} + b_2p^{(n+r-2)} + \dots}$$

$$= \frac{1}{p^r} + \frac{(a_1 - b_1)}{p^{(r+1)}} + \dots$$

If the expansion of the expression corresponding to a pole of order r at $p = (a_1 - b_1)/r$ is made,

$$\frac{1}{(p + (b_1 - a_1)/r)^r} = \frac{1}{p^r}\left[1 + \frac{(a_1 - b_1)}{p} + \dots\right]$$

This may be compared with the series obtained by division, and for large values of p

$$T(p) \simeq \frac{1}{p^r} + \frac{(a_1 - b_1)}{p^{(r+1)}} \simeq \frac{1}{[p + (b_1 - a_1)/r]^r}$$

If the factored form of $T(p)$ is considered,

$$T(p) = \frac{(p - p_a)(p - p_b)(p - p_c)\dots}{(p - p_1)(p - p_2)(p - p_3)\dots}$$

$$= \frac{p^n - (p_a + p_b + p_c + \dots)p^{(n-1)} + \dots}{p^{(n+r)} - (p_1 + p_2 + p_3 + \dots)p^{(n+r-1)} + \dots}$$

$$= \frac{p^n + a_1p^{(n-1)} + \dots}{p^{(n+r)} + b_1p^{(n+r-1)} + \dots}$$

hence

a_1 = −(sum of vectors representing zeros) = $-\Sigma$(zeros)
b_1 = −(sum of vectors representing poles) = $-\Sigma$(poles)

and the equivalent pole is located at

$$p = [\Sigma(\text{poles}) - \Sigma(\text{zeros})]/r$$

APPENDIX B

Saddle point

$$T(p) = \frac{(p - p_a)(p - p_b)\dots}{(p - p_1)(p - p_2)\dots} = \frac{N(p)}{D(p)}$$

differentiation gives

$$T'(p) = \frac{D(p)N'(p) - N(p)D'(p)}{[D(p)]^2}$$

where $T'(p)$, $N'(p)$, $D'(p)$, are differentials. $T'(p)$ can be zero only when

$$D(p)N'(p) = N(p)D'(p)$$

or

$$D'(p)/D(p) = N'(p)/N(p)$$

or

$$\frac{1}{(p - p_1)} + \frac{1}{(p - p_2)} + \dots = \frac{1}{(p - p_a)} + \frac{1}{(p - p_b)} + \dots$$

If there are no zeros, $N(p) = 1$, and $T'(p)$ can be zero only if $D'(p) = 0$ or $1/(p - p_1) + 1/(p - p_2) + \dots = 0$.

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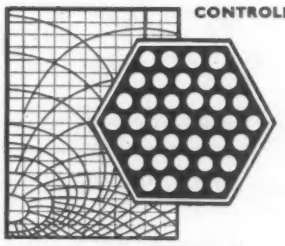


CONTROLLING NUCLEAR POWER—8

In this, the last-but-one of our special series on the control of nuclear power, the author describes what has been found to be the most suitable method of boiler-feed regulation in Britain's first atomic power stations

Supply and regulation of boiler feed-water

by **J. W. W. SHAW**
U.K. Atomic Energy Authority

IN ANY STEAM-RAISING EQUIPMENT THE STEAM GENERATED must be replaced by an equal quantity of water if normal operation is to continue. There are many ways of feeding boilers, but the only one which will be considered in this article is the method which has been found most suitable for the Calder Hall and first-phase civil nuclear-powered systems, namely, high-pressure feed-pumps forcing the water into the boilers and feed regulators adjusting the feeding rate to match the steaming rate.

SUPPLY OF FEED WATER

The supply of feed water for the normal operation of an atomic installation differs little from that required for a conventional base-load station of similar duty. The significant difference is that, whereas on conventional plant it is possible to shut the heat source off completely, in the atomic case heat continues to be generated by the fission products in the fuel even when the reactor is shut down. To maintain safe temperatures in the reactor, therefore, reliable means must be provided to remove this heat. At Calder Hall, in addition to the normal feed system with duplicate mains and stand-by pumping capacity, there are emergency feed pumps (driven by d.c. motors fed from batteries), capable of removing the fission-product heat. As an additional last-ditch precaution, standard fire-hose connexions have been fitted at the feed-injection points of all heat exchangers, and normal fire-fighting appliances could be used to feed the boilers and cool the reactors were all other arrangements to fail.

REGULATION OF FEED WATER

In a steam boiler it is necessary to separate the water from the steam-and-water mixture coming from the evaporators (*a*) to prevent possible fouling and/or damage to superheaters, turbine blades etc., and (*b*) to produce steam of the desired quality. Separation takes place in what is usually called the *steam drum*. This is most often a horizontal cylindrical vessel, of sufficient capacity and suitable internal design, which reduces the water content of the outgoing steam to an acceptable minimum.

The steam drum performs another useful function. It is not possible to control the feed-water flow to match the steam drawing-off rate exactly. Therefore that surface in the boiler where the steam separates from the steam and water mixture must rise or fall as the two flows get out of step. Since the design is such that this surface (usually referred to as the *water level*) is in the steam drum, where the surface area is large, the rate of rise or fall is reduced to manageable proportions.

In most boiler plant it is undesirable to allow the water level to rise too high or fall too low. If the level rises too much there is a possibility of fouling and damaging superheater tubes and/or turbine blades etc., and if the level drops too far the evaporator tubes may be damaged, and, on boilers using forced circulation, there is a danger of damaging the pumps if their suction inlets become uncovered.

When a reactor is shut down, its power falls exponentially. Consequently it is more economic to draw on some non-pumped supply for *initial* cooling after shutting

down, and to provide comparatively small emergency-pumps for subsequent cooling when the reactor power has levelled off. At Calder Hall sufficient water has been stored in the system to cover this initial period, and the water in the steam drum forms a significant portion of the reserve. It will be appreciated, therefore, that the water level in the steam drum must be high enough to ensure a store of water adequate to cover the period between the cessation of the main feed and the availability of the emergency supplies, should normal feed fail.

FEED-WATER REGULATORS

It will be appreciated from the above account that the function of a feed-water regulator is to ensure that the feed flow matches the steam flow, and that the water level in the steam drum is kept within certain prescribed limits. When associated with atomic reactors a feed regulator has to accept a further responsibility, for variations in feed-water flow can affect the reactor-inlet gas-temperature. Take, for example, the case of a reactor which is on full load when the flow of feed water is interrupted. It will be readily understood that when injection of large quantites of relatively cold water into the heat exchangers suddenly ceases, this will allow a significant rise in the temperature of the gas leaving the heat exchangers and returning to the reactor.

For anyone familiar with feed-water regulators it is comparatively easy to visualize what happens in the combination of a reactor, heat exchanger and turbo-generator under changing load. To anyone not primarily concerned with steam plant is may be a little difficult to follow the overall sequence of events as load conditions vary. The following simplified explanation may assist in the appreciation of the discussions that follow.

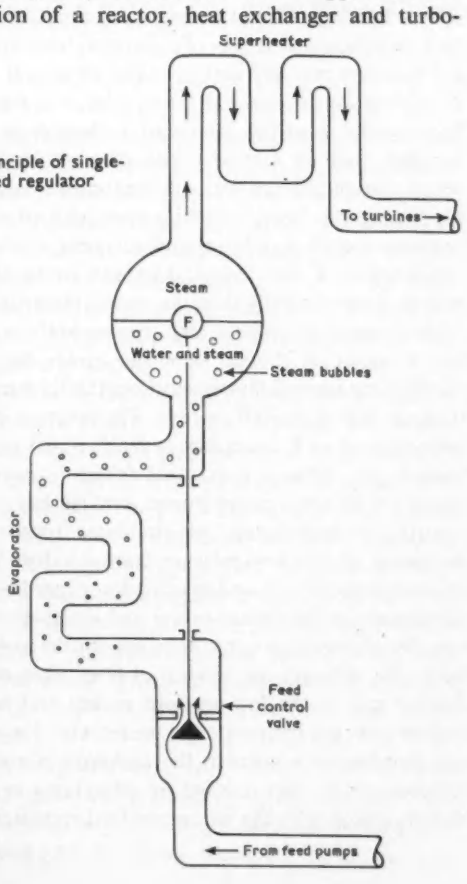


Fig. 1 Principle of single-element feed regulator

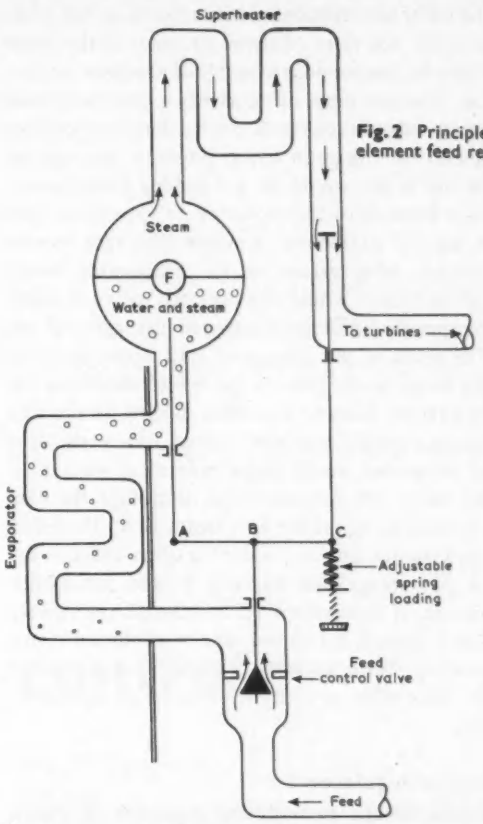


Fig. 2 Principle of two-element feed regulator

Single-element feed-water regulator

One requirement of a feed regulator is that it must keep the water level in the drum between certain prescribed limits. To do this, one of the regulator ' elements ' must be affected by the water level itself. In all types of single-element regulators, therefore, the element must, in some way, be actuated by the water level in the steam drum.

In Fig. 1 an attempt has been made to represent the fundamental principles of a single-element feed-water regulator. In this case a float has been selected to represent the actuating medium. It will be seen that the float *F* will rise and fall with the water level and operate the feed-regulator control-valve. Assuming, for example, that the rate at which steam is drawn off increases, then eventually the water level must fall. This would cause the float to fall, the control valve to open, and the feeding rate to increase. The system would eventually balance when the feed rate became equal to the new rate of steam draw-off, the ' water ' in the drum being finally at a slightly lower level. (It will be appreciated that when reference is made to ' water ' in a boiler, the fluid so described is really a mixture of water and steam bubbles.)

Under steady load conditions the volume of steam

below the water level remains sensibly constant, but, when the load varies, the ratio of steam to water in the boiler alters. Consider the previous example of a sudden increase in the rate of steam draw-off to satisfy a greater demand on the steam side of the system. Such a demand would be accompanied by a drop in steam pressure, and the net effect on the boiler would be (*a*) sudden ebullition of flash steam because of the reduction of saturation temperature, and (*b*) an increase in evaporation rate because the saturation temperature in the evaporator banks would fall and there would consequently be an increase in the temperature-difference between the gas and the water. The result of this change of load would be to increase the steam:water ratio in the boiler and cause the water level in the drum to rise. This in turn, in the case of the single-element regulator, would *reduce* the feed flow, and some time would elapse before the water level would fall below the original value and allow the feed flow to increase to equal the new steam flow. The effect of this load change on the 'water' is often called *swell*, the word describing what happens to the steam-and-water mixture. If steam draw-off is reduced, the reverse happens and there is a reduced rate of ebullition, some of the existing steam bubbles collapse, and the water level falls. This effect is often referred to as *subsidence* or *collapse*.

Two-element regulator

The principle of the two-element regulator is shown diagramatically in Fig. 2. To represent the second element we have chosen a disk connected to the regulator mechanism by a rod through a gland. Pressure-drop across the disk will rise with increase of steam flow and compress the spring at *C*. It should not be imagined that any standard regulator operates in this manner; the device is chosen purely to illustrate the principle.

It will be seen that if the pin joint at *C* remains fixed in space, the arrangement is that of a single-element regulator. It will further be appreciated that, in the case of increased steam draw-off, the 'steam element' will move downwards, tending to counteract the effect of swell on the 'float element' and thus ensuring that the feed flow bears a closer relationship to the steam flow. It will also be appreciated from the diagram that the relative effects of the two elements can be varied by moving the point *B* along the rod *AC* and altering the ratio of *AB* to *BC*.

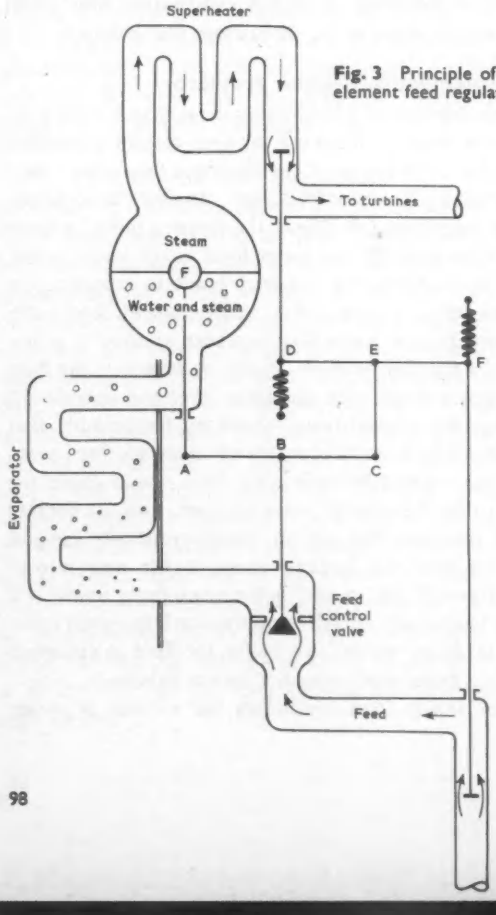


Fig. 3 Principle of three-element feed regulator

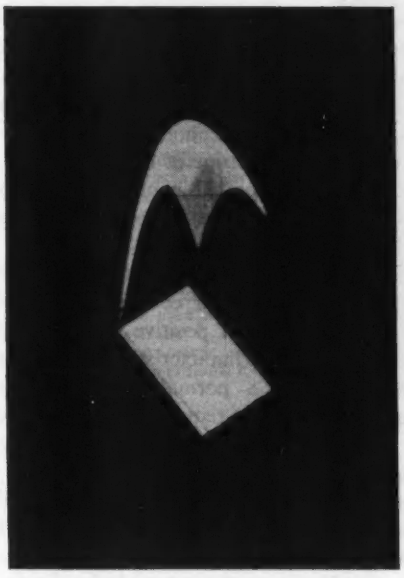
Three-element regulator

An attempt has been made in Fig. 3 to illustrate the principle of the three-element regulator. It will be seen that, if the point *F* remains fixed in space, the rest of the mechanism is that of a two-element regulator. One advantage of a three-element regulator is that any variation in feed flow, say from drop in feed pressure, is automatically corrected by the third element.

FEED REGULATION AND REACTOR CONTROL

Since the Calder Hall Station was the first atomic station generating electricity on a commercial scale, it was essential to be sure that the control system was absolutely safe rather than attempt automatic methods which might lead to difficulties. It was of overriding importance that the fuel elements and certain major structural members (including gas ducting and gas-circulator casings) should be subjected to as few temperature changes as possible, to limit thermal stresses. One member in particular which caused concern was the multi-girder arrangement supporting the heavy graphite core with its charge of uranium fuel. A significant and sustained change in the temperature of the reactor-inlet gas could affect this structure more rapidly than the vessel supporting it. This could cause unacceptably high stresses in the supports if the temperature change were too great. Fig. 7 (next month's instalment) illustrates the method chosen for controlling the Calder Hall reactors. The operator has visual indication of such quantities as reactor-inlet and -outlet coolant-gas temperatures, fuel-element temperatures, steam conditions, reactor power, etc. He has control of control-rod positioning, gas-circulator speed and the presetting of the low-pressure control-valve. Variation of control-rod setting and gas-circulator speed will permit adjustment of the reactor power and outlet-gas temperature. By raising or lowering the pressure in the low-pressure boiler, he can vary the amount of heat taken out of the coolant gas by the low-pressure system and adjust the reactor-inlet gas-temperature. One feature over which the operator has no control is the variation of coolant-gas temperature at inlet, caused by alterations in the feed flow as adjusted by the automatic feed regulators.

To be continued



PART 1

How can one tell whether this provision or that dodge is really necessary? To discriminate between the essential and the trivial measures it is necessary to have a well-substantiated logical basis on which to assess adaptive systems

Adaptive control

by **J. H. WESTCOTT** B.Sc.(Eng.), Ph.D., M.I.E.E.
Imperial College of Science and Technology

FOR SOME TIME NOW THERE HAS BEEN A SUSPICION AMONG the fraternity that something is astir in the undergrowth of automatic control. Could it be the effect of spring? With the sun of Government approval not yet shining in this direction that has seemed improbable, but a whisper has remained. In the last month or so it has mounted to a distinct rustle in the woods—*something* seems to be in the wind. What is it all about, and what is this adaptive business anyway?

At present it is probably no more than a signpost pointing into the future, but the suspicion that important new advances in the possibilities of automatic control are about to unfold is remarkably wide-spread, and is clearly discernible in publications from the United States and the Soviet Union and many other countries. The proceedings of last year's Ifac Congress hummed with a mysterious something, but it was difficult to come to grips with it through the haze of differing notation and methods of presentation. Now that there has been time to unravel the skein and set it alongside our own efforts, it is possible to discern in outline what might be involved.

The first thing that seems to be widely realized is the need for a more comprehensive theory to handle the problems that arise with the prospect of modern integrated control of industrial processes. With the convergence of a number of trends, demands are being made on theory that require it to have greater power as a guide in the search for new systems of control. Systems that are being considered as a whole are becoming larger and more powerful. The responsibility for controlling them demands more embracing and closer control, a wider diversity of control, and greater precision of control: this at a time when large and very reliable digital computers, capable of great versatility in control action, offer promise of being fit to meet such exacting requirements. Existing servo-mechanisms theory is no match for analysis of these exciting possibilities; something is needed more in keeping with our ambition. There are clear signs that the required theory is emerging, and, perhaps not surprisingly, it is proving to have a basis which is fundamentally scientific. This may mean that we shall to do a little unexpected homework, and it is not much consolation to know that the basis of it was formulated long before there *was* any control theory.

HILL-CLIMBERS

Perhaps the easiest way to build up the framework of the new theory is to start by considering some simple examples of adaptive systems and to show where the present theory is inadequate for design analysis. One of

the simpler types of adaptive system is the hill-climbing device. This is at its simplest under noise-free conditions, when it is required only to be able to operate a system at its peak of efficiency even though the peak drifts with respect to the control variables. An immediate difference of viewpoint from normal servo-mechanisms theory is detachable in the use of the idea of 'efficiency'. Efficiency is a very general criterion, and much more difficult to define than the very specific 'error' of servo-mechanisms theory. Unlike error, efficiency is never negative, but it tends to be small at either extreme of operating conditions. The hill-climbing device is most suitable in circumstances where these two low-efficiency zones are joined by a characteristic having a unique maximum. Fig. 1 shows a two-dimensional climbing device ascending a very tangible tin hill. This illustration is taken from a short film made by the Electrical Engineering Department of Queen's University, Belfast, and shown by Dr Douce at an I.E.E. Discussion meeting on self-adaptive control systems on 21 March last. In the film the probe head was shown nervously nudging its way up the side of the hill, operated by the responses to perturbations deliberately introduced to determine the slope of the hill and to enable the device to head upwards along a path with maximum slope.

Principal modes of operation

Three principal modes of operation of these hill-climbers were mentioned by Dr Blackman (of pole-zero fame*) in his lecture at last month's Exposition of Adaptive Control (E.A.C.) at Imperial College, characteristically backed up by experimental demonstration.

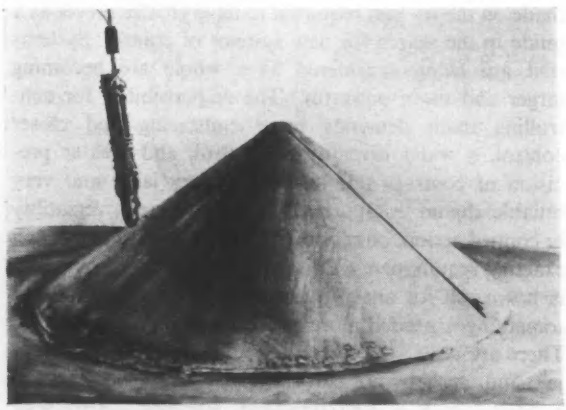


Fig. 1 Two-dimensional hill-climber in action

The simplest of these methods measures the slope of the characteristic by driving the control variable at a fixed rate. When the slope changes sign and builds up to a predetermined magnitude in the new direction, a relay reverses the direction of the drive. Thus, when there is no drift in the characteristic, the system hunts continuously about the maximum. The greater the sensitivity of the relay, the smaller is the excursion. On the other hand, a lag in the system causes a time delay in the rise of the output response, and this tends to increase the excursion. The type of response obtained then is shown in Fig. 2. This photograph of the response was taken on the oscilloscope of Dr Blackman's demonstration of the relay-type hill-climber with dynamic lag, and the limit-cycle performed once the maximum has been reached is clearly shown.

The second mode of operation is the self-driving, which is a proportional control version of the relay type, having in effect positive feedback operating on the measure of the characteristic-slope, forcing its value to zero as does a normal servo-mechanism. These systems unfortunately require a jerk to get them moving, and will stick once the slope has been reduced to zero. If they overshoot they drive hard away from the desired operating point. These little operational difficulties can be overcome by measuring the slope of the characteristic from direct division of corresponding increments along each axis. However, the presence of a divider makes the system essentially non-linear and difficult to analyse. Also, with a dynamic lag in the system it still sticks. With addition of further palliatives the system can be improved, but the design is by then rapidly deteriorating into an *ad hoc* one.

And so we arrive at the third mode of operation, in which a perturbation of the control variable is introduced and sought in the output response by means of a demodulator whose smoothed output is positive or negative on opposite sides of the maximum. This method has the considerable advantage that, if the characteristic is of parabolic form (and many practical ones are reasonable approximations to this), then the control action is linear. The control system can be designed by standard servo-mechanisms theory. Such theory is not ruled out at this stage, but a different viewpoint has to be adopted concerning the motive of control. Complications arise in evaluating performance, since the end result is expressed as variations of a performance index which is not linearly related to the control action. A further advantage of this last method is that it is relatively easy to extend it to more-than-one-dimensional characteristics. Since the perturbation frequency and demodulator can be particular to a given dimension, and (over a long enough averaging time) virtually independent of any other perturbation frequency belonging to another dimension, the additional equipment for multi-dimensional control is only linearly increased with dimensionality. In Fig. 3 Dr Blackman shows an isometric view of a two-dimensional-perturbation hill-climber, climbing in one dimension during the first part of its trajectory to a peak on this particular section in the two-dimensional solid. A second control variable is then brought in, acting perpendicularly to the first, and the device climbs to a maximum in this new direction (as shown) during the second part of its trajectory. Allowing both control variables to act at once will cause the

* The current instalment of Dr Blackman's series on the pole-zero approach appears on p. 92ff.—EDITOR

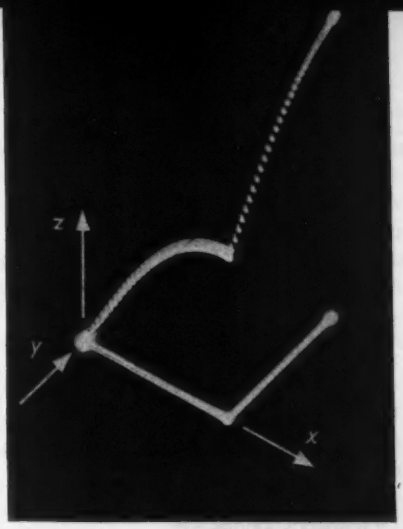


Fig. 2 (bottom right) This oscillogram shows the limit cycle performed at the peak

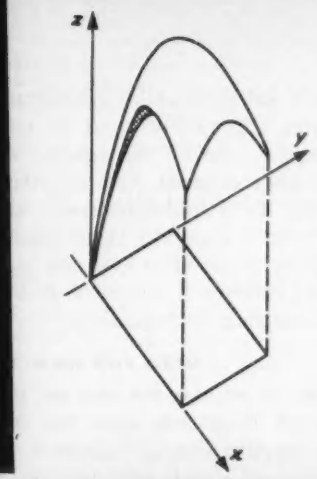


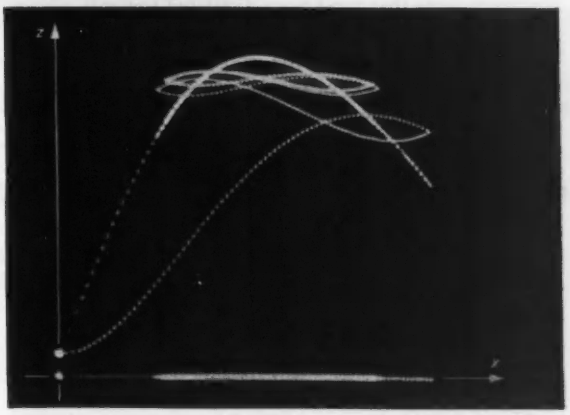
Fig. 3 (centre) Oscillogram giving isometric view of a two-dimensional-perturbation hill-climber's action

Fig. 4 (top right) This diagram is taken from the oscillogram used for the title illustration on p. 99. It shows an isometric scan of a two-dimensional hill

device to take the steepest path to the peak, in the absence of dynamics and cross-coupling between control variables. A variety of interesting effects occur when the latter are present, such as spiralling up the hill owing to cross-coupling, which can readily be investigated if one can first catch one's hill and arrange to display the results. In Fig. 4 is shown an isometric scan of a two-dimensional hill discovered in the South Kensington region during the E.A.C., reputed to be based on two bob's worth of discarded Metrosil.

CLIMBING NOISY HILLS

It is only fair to acknowledge that the performance index can rarely be measured precisely in practice. Most frequently it has to be assessed indirectly, using measurements whose accuracy is not high and which are subject to random scatter. Thus the determination of the slope of the performance characteristic is by no means so straightforward as it might sound, and this fact has considerable influence on the control performance that can be achieved. These matters were given an airing at an S.I.T. meeting on 28 March last, at which a rather 'difficult' paper was presented by Grensted and Jacobs on 'Automatic Optimization'. The difficulty was perhaps built into the paper rather than intrinsic to the subject. It is clear that probability has to be used, and it is sensible to start with the much simplified case where the probability of the polarity of the slope being estimated correctly is all that is known, and to assume that the control variable moves in fixed steps. The snag about this approach is the difficulty of relating the results obtained to design improvements in the control action. The design of stepping controllers on the basis of probabilistic estimates is not a well-worked-out art. The bull was taken decisively by the horns by Lyle, in a study presented at the E.A.C., in which he made a frontal attack on the problem in this form by digital computer. A comparison with analytical results taken from the work of Feldbaum showed that this method has promise. Grensted and Jacobs go on to discuss linearization of the hill-climbing system, which is much more promising, but stop short of allowing the system to become a continuously acting one, which would have



brought us back to the familiar territory of linear-filter theory—a well-worked pitch. At one point the authors may be converging on this desirable end, and it is in this respect that the paper goes decisively ahead of anything available elsewhere. Their advance is in the relationships derived for the case of very small step, when the probability of correct slope-polarity approaches $\frac{1}{2}$, which gives a useful analogy with Brownian motion and enables one to write down a Fokker-Planck type of partial differential equation for the probability distribution. This is very promising, and is clearly related to work (mentioned by Florentin during discussion of the paper), on more general application of distribution functions to transient behaviour of systems. He also reminded us that G.E.P. Box is a hill-climber from way back. This is often overlooked, because his methods were applied entirely off-line, whereas current interest is almost entirely on-line.

Certainly the hill-climbing technique is for the present receiving most attention from those intent on practical application, including Elliott-Automation and de Havilland's. At the I.E.E. meeting P. H. Hammond described work being done at the National Physical Laboratory on hill-climbers of a somewhat more sophisticated type, involving three integrators in cascade, in which parameters are adjusted according to short-time estimates of correlation coefficients. The device was demonstrated in action at the Physical Society Exhibition. Hammond

explained that stability considerations are not so simple where adaptability is to be commensurate with the reaction time of the system. At the S.I.T. meeting already mentioned, Rees described further work of this group on a four-dimensional hill-climber using feed-forward as a counter to the difficulties experienced with this technique when long time lags occur in the process being controlled: shades of the invariance principle and the enthusiastic Ivakhnenko! *

NEED FOR NEW THEORY

So far we have not seen any pressing need for a new theory. It certainly seems true that one can get started on adaptive systems without it. However, the diligent reader will already have discerned a tendency among the simple systems that have been discussed towards *ad hoc* improvisation. No bad thing perhaps, if it is really necessary—and there is the rub. How can one tell whether this provision or that dodge is really necessary? To discriminate between the essential and the trivial measures it is necessary to have a well-substantiated logical basis for the assessment of adaptive control systems. 'Adaptive control' is here used in the broad sense, covering hill-climbers, automatic optimization, continuous variational methods, dynamic programming (or discrete variational) methods, self-organizing systems —the lot! Used in this sense, adaptive control is not just another brand of goods, it is a whole supermarket itself, wherein we may buy many marvellous wonders in the control-system line. As in all supermarkets, there is the ever-present need to choose with moderation to suit economic reality. Let the taped fanfare of trumpets play, but when it comes to the reckoning it has to be value for money or folk may not shop there again. This then is the important problem—to establish logic for adaptive control, to provide standards of reference whereby one system of adaptive control may be compared with another. While this is lacking there can be no guarantee of progress, or, what is perhaps worse from a practical engineering point of view, no way of estimating expected economic returns before installing a proposed and conceivably expensive adaptive scheme. A real possibility of making such calculations would have a value for the industrial future of modern integrated process control which could hardly be overstated in the current stage of competitive enterprise in this field.

The evaluation of adaptive control systems requires three essential components of theory which may be summarized as follows:—

1. Need to arrive at a detailed specification of the physical structure of the system and the determination of a valid performance index (system analysis).

2. Requirement for a detailed statistical analysis of variables, whether signals or system parameters (stochastic analysis).

3. Necessity to calculate a dynamic control strategy using available control variables, from an application of a maximization principle (variational analysis).

* See e.g. 'New Methods of Control-system Investigation' by A. G. Ivakhnenko, *Control*, Dec. 1960, p. 96.—EDITOR

Each of these items is related to an existing body of theoretical analysis (shown in brackets at the end of each), which, when properly formulated, will form the framework of future theory Although easy to state, it is not yet possible to string them altogether in a convincing way; to do this is the subject of current research, and is the problem on which known viable groups in several major countries are urgently working. There is evidence (*vide* E.A.C.) that one such group at least is at work in this country.

Engineer's jaundiced view

What is the ultimate motive in controlling a system, and how ideally should this be done? All systems requiring control work in an environment of random disturbances. If enough can be discovered about the underlying physical basis of the system or process to be controlled (and this may have to be estimated from such evidence of response as may be measurable), then it will be possible to predict what the consequence of a particular observed disturbance will be throughout the system. At least in the interregnum, until a further disturbing event occurs somewhere in the system, it will be possible—if the sum can be done quickly enough—to act on all control variables within the limits of their available span, so that the performance index is maintained at its maximum permissible value in spite of the original disturbing event. If this is done for all disturbances as they are detected, or are inferred to have occurred anywhere in the system, then one has an optimal system. Should this sound delightfully simple, take an engineer's more jaundiced view of the situation. First of all recall that this is to be an *adaptive* system, implying that the signal environment is changing, and that therefore means must be found to describe this state of flux; the system itself has parameters which change with time, so that this business of specifying the system has to be continuously evaluated on the evidence of such change. Remember that the control system is not designed yet, and it is still an open question as to how this can best be done, so the particular signals are not of so much value as representative signals—that is to say, the underlying statistical generators belonging to the signals, and the way in which they change with time, are more important than the signals themselves here, and these parameters have to be estimated. Finally, there is that awkward bit about 'if the sum can be done quickly enough'. The sum to be done must ensure that the performance index is maintained at its maximum permissible value; so the sum must be based on a maximization principle, using the calculus of variations perhaps to ensure that this is so: even this is not quite good enough, since the control variables have limited excursions, and the maximum may not be inside the field of variation but on a boundary. It now sounds quite difficult, but the relevance of the three components of theory is perhaps becoming clear.

To be continued

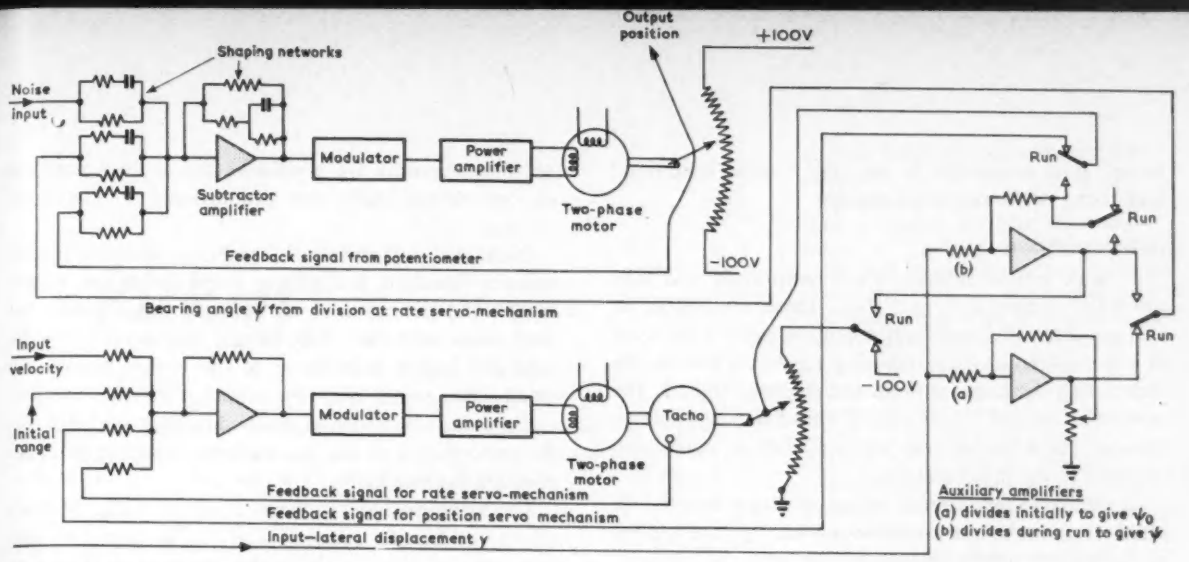


Fig. 7 Block diagram of servo-systems

PART 2

Versatile analogue computer for g.w. studies

by **MICHAEL G. HARTLEY** M.Sc.Tech.
Manchester College of Science and Technology

The simulator was generally described and the computing elements discussed in Part 1 last month

SERVO-SYSTEMS

Two rate and two positional servo-systems are available for use in the machine. The position servo-mechanisms provide initial bearing angles for missile and target, and move slowly round during a run to give bearing angles throughout. Target and missile ranges are indicated by the two rate servo-mechanisms. As in the case of the bearing servo-mechanisms, the output is taken as a voltage from a potentiometer mounted on the output shaft. At i.c. they are connected as positional servo-mechanisms. The output voltage shows initial range. During runs they are connected to function as rate servo-mechanisms. Their rate is proportional to missile or target velocity. The voltage at the output potentiometer at any time indicates range.

In order to simplify the simulation as far as possible, the small-angle, two-dimensional, case has been taken. Bearing angles have been restricted to $\pm 15°$. This permits the simplification $\sin \psi \simeq \psi$ where ψ is the bearing angle in radians. Accordingly, it is possible to obtain a bearing angle, with respect to a datum direction, by the division

$$y/R \simeq \psi \qquad (6)$$

where R is range and y is lateral displacement from the datum direction.

For the reasons discussed below (under *Bearing servo-mechanisms*) it was decided to use an a.c. servo-system. The introduction of an a.c. system, however, caused certain difficulties. The simulator is essentially a d.c. system. The servo-motors chosen were two-phase 400 c/s Muirhead motors. In order to drive them a 115 V, 400 c/s supply is required for one phase. This is taken direct from a power amplifier.

The error signal is required to energize the control phase of the motor. Since this is an a.c. system, the d.c. error signal requires modulation at 400 c/s, followed by power amplification. It is also necessary to provide a phase-shift network to ensure that the two phases supplied to the motor are in quadrature.

A modulator and push-pull output stage are carried on a sub-chassis. The circuits are conventional. The a.c. reference voltage, 10 V r.m.s., 400 c/s, was chosen so that it was large compared with the maximum d.c. input signal. The square-wave output is applied to a single-stage tuned-anode amplifier followed by a phase-splitting stage to provide the push-pull drive for the power amplifier which follows.

The power amplifier, on a separate sub-chassis, is a push-pull arrangement to provide 9 W to drive the servo-motor. The output is transformer coupled into the motor winding. A feedback winding provides a degree of stabilization. The motor windings are arranged for 58 V maximum working.

Range servo-mechanism

The range servo-mechanisms have a dual function. They indicate range, both initially, and during a run, and they also perform the division $y/R \simeq \psi$ for missile and

target. It is convenient to consider ' initial condition ' and ' run ' performance separately.

Initial conditions

The range servo-mechanisms act positionally and take up initial ranges R_{TO} and R_{MO}. These are applied as voltages from the coefficient potentiometers at the front of the machine to the computing amplifiers used as the subtracting elements for input and feedback signals. The servo-mechanisms rotate until the feedback signal from the potentiometer on the output shaft is equal and opposite to the input voltage.

At the same time, initial values of target and missile offsets from the datum direction y_{TO} and y_{MO} are applied *via* coefficient potentiometers to the input of auxiliary computing amplifiers. These have a potentiometer across their outputs, the slider of which is set to the same value as that of the output potentiometer on the servo-mechanism. The feedback resistor is taken from input grid to the slider. With the scaling suitably arranged the result is that the amplifier performs the division $y_0/R_0 \simeq \psi_0$ for missile or target, to give the initial bearing ψ_0.

Run condition

On switching to ' run ', the range servo-mechanisms become rate servo-mechanisms. They rotate at a speed proportionate to the input target and missile velocities, which need not be constant. They are set in as voltages

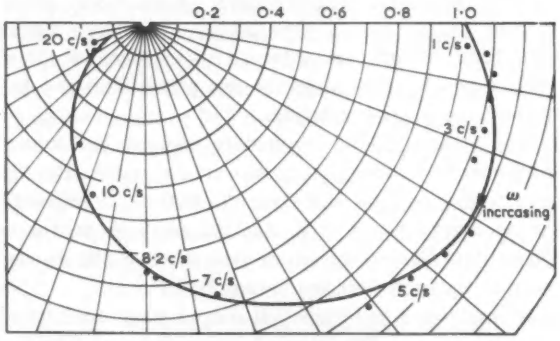


Fig. 8 Frequency response of positional servo-mechanisms

at the d.c. amplifier used as the subtracting element. Range is indicated by the position of the output shaft at every instant. Rate feedback is applied from a d.c. tacho-generator geared to the output shaft of the servo-mechanism. Position feedback is no longer applied. The output potentiometer is now used to perform the division $y/R = \psi$ in a way similar to that employed during the ' initial conditions ' period.

The block diagram of Fig. 7 shows the circuits used for both range and bearing servo-mechanisms. They are the same for missile and target.

Bearing servo-mechanisms

Input voltages representing target and missile bearing angles are applied to the inputs of the bearing servo-mechanisms. They are derived from the rate servo-mechanisms as described above. Since the bearing servo-mechanisms are positional, the angular positions of the output shafts are proportional to the input voltage.

Because it is desirable to be able to simulate tracker transfer functions and tracker noise during the experiments, the performance of the servo-mechanisms has been made such that their natural frequencies are considerably higher than those of the typical tracker for small signal amplitudes. Hence tracker transfer functions and noise can be added as required in the knowledge that the performance of the bearing servo-mechanisms is not affecting the results.

The servo-mechanisms were designed, using Nichol's charts and transfer function analyser, to have a natural frequency of about eight cycles per second. This was attained with lead-lag networks round the d.c. amplifiers used as subtracting elements. The d.c. gain of the servo-systems was arranged to have a large value in order to minimize the velocity lag.

The gear ratio from motor shaft to pick-off disk was such that the inertia of the pick-off disk reflected back to motor shaft was negligible. Hence the inertia of the system was essentially that of the motor alone. For the servo-mechanism to have a fast response under these conditions, the torque:inertia ratio of the motor is important. For the range of power outputs required, a.c. motors offered the best torque:inertia ratio. For this reason an a.c. system was used as described above (under *Servo-systems*).

Fig. 8 shows the frequency response of the positional servo-mechanism.

SUCCESSFUL OPERATION

The machine has been in operation for some eighteen months without serious fault. The operational amplifiers function well. Valuable data about missile performance has been obtained by the use of the machine.

Acknowledgements

Thanks are due to Ferranti Ltd for permission to publish this paper. Thanks are also due to Dr C. M. Cundall, Mr J. K. Saggerson, and Mr D. Butler for their valuable advice during the preparation of material. Special acknowledgement is due to Mr Saggerson for his co-operation with the sections dealing with the operational amplifier.

APPENDIX

Refer to Fig. 7. Let the gain of amplifiers I and II be nominally unity. In actual fact the gains will be

Amplifier I	$(1 + \delta a_1)$
Amplifier II channel x	$(1 + \delta a_2)$
channel y	$(1 + \delta a_3)$

Consider case No. 1

With the circuit as shown, let the input voltage be V volts. The output voltage will be $V(\delta a_1 + \delta a_2 - \delta a_3)$ (1)
if second order small quantities are neglected.

Consider case No. 2

With the reversing switch in operation, the output is,

$$V(\delta a_1 + \delta a_3 - \delta a_2) \quad (2)$$

Adding (1) and (2) we have, $V_{output} = 2V\delta a_1$ (3)

Hence this method gives a measure of departure of amplifier I from the desired gain—in this case unity gain—without the need for accurate measurement of two nearly equal quantities, or for exactly equal gain in channels x and y of amplifier II.

End

Pick-off

by 'UNCONTROLLED'

DO YOU REMEMBER *the copybook* arguments for automatic control — greater accuracy and higher consistency than can be achieved by a man, tirelessness, speed, and all that? Now the modish thing is to hold up man himself as the model control system, equipped as he is with an on-line computer so cunningly milli-micro-miniaturized as to fit into a skull. The cyberneticians are doing their best to produce a self-adaptive robot which, if it is a close copy of the biological original, will presumably suffer from inaccuracy, inconsistency, fatigue, and all the other ills that old-fashioned automation was going to cure. Is there a paradox here, or am I just being silly?

ALL SORTS OF CHORES come my way. Clearing one of them the other day I found myself needing some quite simple and not very technical information about a proprietary component. I rang the makers, and after five minutes or so of patience I got through to a young-sounding man who was willing to 'speak to the people concerned'. He did, and the subsequent dialogue went something like this:

UNCONTROLLED: What voltage is needed?

YOUNG MAN: Oh, twelve watts holding, 48 volt-amps surge.

UN: Yes, but what *voltage*?

YO: I'll check.

(*Five minutes of silence.*)

YO: Any voltage.

UN: A thousand volts, say?

YO: They said *any* voltage, because the power will vary with the voltage.

UN: Oh!

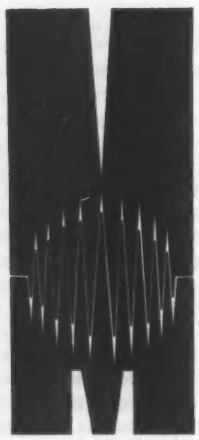
We went on in this vein for about another quarter of an hour.

This is not at all unrepresentative of the kind of response I get from companies around the country. What beats me is that so many of them go on making a living. There are information departments that act more as smoke screens than as data transmitters. I realize that the journalist's job is to dig for information, but must it call for a steam shovel?

AN AMERICAN visiting lecturer at one of our universities has been telling a friend of mine how much he admires British fundamental work on automatic control, and how apt he thinks all this is for the country's needs. 'You must automate or die', he said, and went on to deplore the backwardness of British management in understanding this necessity. The trouble is that British management too often consists of people who just won't try to understand technical matters. They talk loftily of their responsibility for higher policy and their need to rise above detail, and then settle back more comfortably to enjoy their expense-account lunches. I am reminded of Professor Parkinson's exquisite story of the board of directors which quickly passed highly technical business involving costs of millions, but went into long and minute discussion over inexpensive items that were within their comprehension. I wonder how often a profession of concern for 'higher' business policy conceals either indolence or a distaste for scientific and engineering ways of thought? It is frightening to accept that our American friend may be right, and that this country's industry may die through the mental laziness and ill judgement of many boards of directors.

FORTUNATELY there are *some* people in high places who know better. 'The engineer is in fact the means by which the people are able to enjoy the fruits of science, whether in building new projects, or in maintaining and keeping up to date what is already in existence. I need hardly list the highly developed communities of history which decayed for the lack of engineers to keep their great works in operation.' These words were spoken by the Duke of Edinburgh last month when he read this year's Graham Clark Lecture to the senior institutions at the Inst.C.E. I was among the lucky ones in the ballot for tickets, and I thoroughly enjoyed the Duke's broad-ranging survey. I do not think I have heard anybody better his description of the engineer's part in the material development of nations: '1. By continually finding practical ways and means of applying scientific principles and discoveries in power, industry, transportation, communication and construction. This means that research establishments are needed in all the divisions of engineering so that practising engineers can apply the benefits of fundamental scientific research. 2. By the application of the latest and most efficient methods to individual projects. This means that practising engineers must have some way of keeping up to date. 3. By the careful administration, maintenance and improvement of the engineering complex. Building or developing some project from scratch may have a great many difficulties, but maintaining and improving a project which has been in existence for many years calls for even more skill and administrative ability. Railways are an obvious example. 4. By the technical training and education of the next generation of engineers. This is very much the engineer's responsibility and whatever the rewards of practice may be nothing is more worth while in the long run than teaching the next generation.'

WHY ARE certain self-adapting systems called self-optimizing by Britons and self-optimalizing by some Americans? The latter must differ in outlook from those of their countrymen who have cut down 'automatization' to 'automation'. I am a lazy writer myself, so naturally I prefer the shorter word, but I'll give way if there is a good reason for the longer one. Analogy, as so often, may be misleading here: nevertheless, to coat with aluminium is to aluminize, not aluminalize, and to reduce to a minimum is to minimize, not minimalize. On the other hand, if you convert to decimal fractions you decimalize, and if you protect your equipment against tropical conditions you tropicalize. Perhaps there is a shade of difference between the two usages. Maybe aiming for *an* optimum is optimizing, while seeking an optimal *situation* is optimalizing. The practical distinction between these processes is too slippery for me to grasp, however. Webster, the authoritative American dictionary, gives the word 'optimize' (not 'optimalize', at least in my edition) and says that it means to treat optimistically. Judging by some of the high-flown literature on the subject, I think Webster is right.



Mesucora preview

The French international instrument exhibition, Mesucora, will be held at the C.N.I.T. hall in Paris from 9 to 17 May. It is the first French exhibition of its kind, and looks like being on the same scale as Germany's Interkama and our own I.E.A. It is combined with the 58th exhibition of the Société Française de Physique.

This new-style French instrument exhibition, being analogous to a combination of our own 'Phys.Soc.' and I.E.A. exhibitions, will contain equipment from many fields, some not directly related to control engineering. This short preview sets out to give an idea of the scope of the exhibition. It is not possible here to mention all equipment likely to interest readers, but an attempt has been made to select the material more significant from the control engineering point of view, while at the same time giving a not-too-distorted picture of the exhibition as a whole.

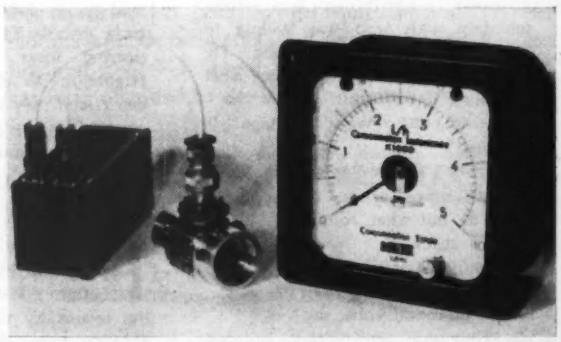
Process instrumentation

A wide range of millivolt indicators and recorders, mainly intended for temperature measurement, will be on show. Guerpillon will present a new miniature indicator/controller using photo-electric switching for two-step control. Ranges of equipment for **temperature measurement and control** will be shown by A.O.I.P.* and Camille Bauer, the former firm's products including a miniature six-point instrument, in which the ranges of the six points may be chosen independently. Camille Bauer's range includes two-step controllers with a built-in thermal lag device, claimed to improve performance, and a transducer suitable for converting resistance-thermometer measurements to a standard transmission signal. A major attraction is likely to be the first presentation on the European market of the new Honeywell Elektronik 17 recorder, incorporating a novel strain-gauge bridge in place of the conventional slide-wire (see page 114 for details). Pyrometrie Industrielle will display a number of temperature instruments, including a multi-point recorder/controller having a special optical device to facilitate reading at a distance, and West Instrument will show their Gardsman stepless controller working on the saturable-core reactor principle. Merlin and Gerin have a six-point potentiometric recorder capable of independent control from each of the six points.

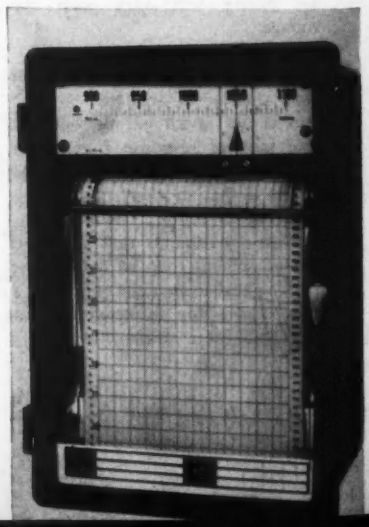
Amongst the **control valves** exhibited will be ranges by Hunt and Mitton (at the Francel stand) and A.D.A.R., the latter range including a valve with a new type of actuator for use with electrical control schemes (see page 113). In the field of **flow measurement,** the problem of measuring very small flows seems to be receiving attention. Faure-Herman will show, in addition to a range of 'propeller'-type meters, a meter designed for flows of the order of a few litres an hour. This works on the principle of filling two flexible containers alternately. Meters for even smaller flows, and working on a thermal principle, will be found on the D.A.M. stand (see also page 114). Krohne rotating-float flowmeters with transmitters incorporating a linearizing device will be exhibited by Trouvay and Cauvin.

An accurate device for **measuring absolute pressure** will be shown by Desgranges & Huot, using rotating pistons and a reference vacuum maintained by a pump. Jules Richard will exhibit a new **pressure transmitter** in which the movement of a Bourdon-type tube is detected by a differential transformer. Telco have a range of pressure transducers working on the variable-inductance principle; it is claimed that these transducers will respond to pressure variations at frequencies up to 1000 c/s, or up to 5000 c/s to special order. Bourdon present a new low-range pressure gauge (0–250 mmH_2O) in which all parts which come into contact with the fluid are of stainless steel. This gauge can be fitted with various contacts for controls or alarms, or with a transmitting potentiometer. Arca will show a **pressure regulator** having proportional and integral action, specially designed for maintaining constant pressure at the inlet of a gas-flow control valve.

Also on the Arca stand will be various specialized **instruments for specific industries,** including an instrument depending on conductivity measurement for recording and controlling supersaturation in the sugar industry. Of particular interest to the petroleum industry will be the Texas Instrument's Data-gage remote **liquid-level** measuring system, to be seen at the Lindqvist stand. Regulateurs Francel will exhibit both laboratory and



Faure-Herman rotary flowmeter with indicating equipment, and (below) electronic multi-point recorder recently introduced by Georg C. K. Withof



* A table of initials and their meanings appears on p. 108

industrial equipment, including a calorific-value controller developed for the automatic control of coke-ovens.

Taylor Instruments will be showing a range of process instrumentation equipment similar to that marketed by Taylor Controls in the U.K.

A display showing the use of the Ekco **nucleonic density gauge** will appear on the Jouan stand. This gauge provides a non-contact measurement of liquid density, and is claimed to detect changes in s.g. as small as 0·002. One suggested use of this gauge is the detection of the interface between the different grades of oil in a pipeline.

Machining

Information so far available to *Control* suggests that the amount of material on show in the **machine-tool control** field will be relatively small. An exception will be the S.E.A. stand, where a number of accessories in this field will be seen. These include a linear transducer with digital output, an angular encoder, and the Servalco printed-circuit motor, which combines low inertia with good angular resolution. Some **machine-tool attachments** will be shown, including a new pneumatic-hydraulic boring attachment by Koenig, intended to work in conjunction with transfer machines on mass-production lines. S.A.G.E.M. will show optical rotary tables and dividing heads. Also on the S.A.G.E.M. stand will be a range of magnifying **profile-projectors** for the examination of work pieces (e.g. screw threads). A range of Hauser equipment performing the same function will be seen on the Stockvis stand, and another instrument of this type will be shown by Physique et Industrie.

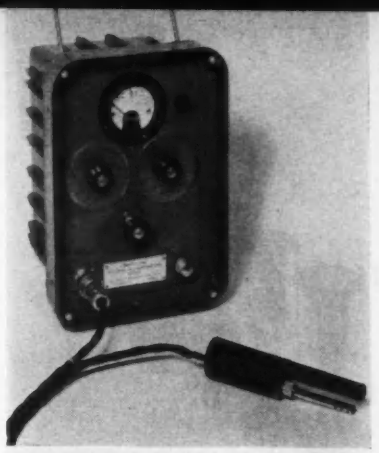
A representative selection of Mercer **air gauging** and **dial gauging** products will be shown on the Goldring stand. This will include the Ultra-Hi-Mag air gauge having a 6 in dial reading to 0·00025 mm. The Etamic comparator gauge, working on a pneumatic-bridge principle, will be seen on the stand of Ateliers de Normandie. An electronic comparator for which a measuring accuracy of 1/10th micron is claimed will be exhibited by Manuhrin, who also have a narrow-tolerance gauging head for routine checking of mass-produced components.

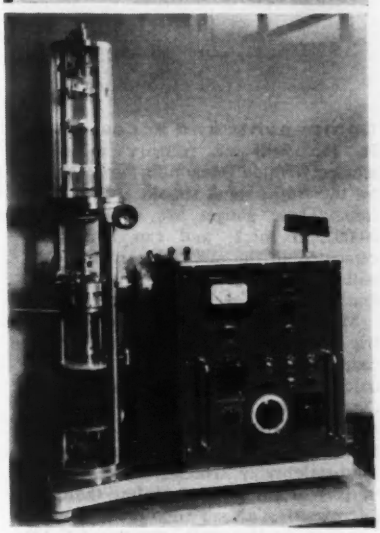
Codima will show a Jackson & Bradwell dynamic balancing machine, having automatic indication of the amount and position of unbalance.

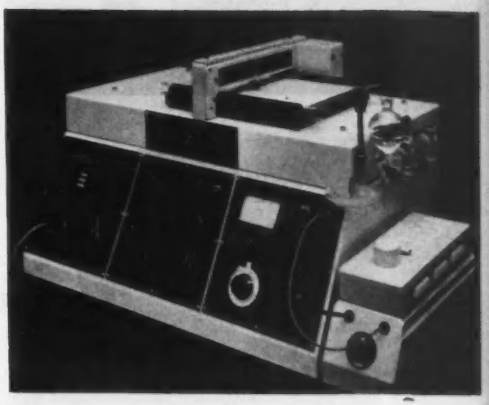
Analytical instruments

Most of the analytical equipment to be exhibited has been designed for laboratory use, rather than plant applications. Numerous **spectrometers** will be on show, including the new Varian A–60 which claims to make nuclear magnetic-resonance spectra easily obtainable on a routine basis. This instrument is making its first appearance in Europe. Another new instrument, the Fabry-Perot spectrometer, designed for high-resolution spectroscopy in the region of 0·3μ to 2·0μ, will be shown in prototype form on the Jobin & Yvon stand. Infra-red **spectrophotometers** and a double-beam ratio-recording instrument for the ultra-violet, visible, and near infra-red regions will be shown by Beckman, while S.A.F.A.S. will exhibit three spectrophotometers covering the region between 1800 and 10,800 Ångstroms. A new wide-dispersion Huet spectrograph having a cell focal-length of 3·5 m will be on show at the stand of the Société Générale d'Optique. Thomson Houston will show a mass spectrometer developed specially for measuring small concentrations of deuterium in hydrogen.

In the field of **chromatography,** Paris-Labo will show an automatic fractionating column and Shandon automatic vapour-phase analysis equipment. Beckman will have laboratory gas chromatographs and the Megachrom preparative gas chromatograph, designed to handle gas samples much larger than those used in normal practice. Georg C. K. Withof will exhibit the Okometer, an instrument working on a light-absorption principle, and claimed to be more suitable than infra-red analysers for certain applications.





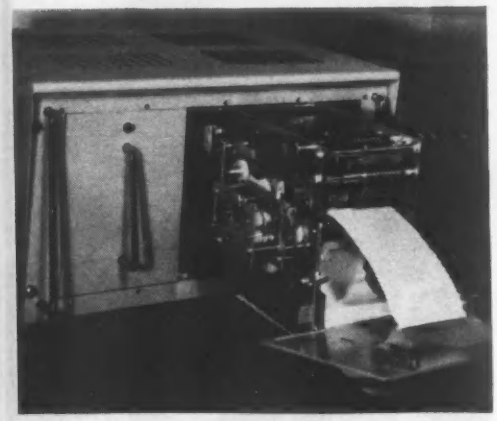


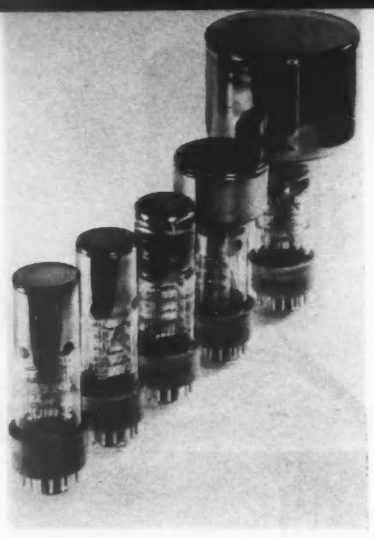
Top left: New Wayne-Kerr portable chlorinity/temperature bridge. Top right: One of a range of profile projectors (S.A.G.E.M.). Bottom left: 'Microconsistomètre' for study of rheological properties of melted products (D.A.M.). Bottom right: Ouéré automatic recording titrator (Antarès)

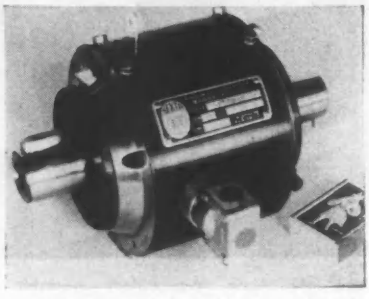
Test equipment and portable instruments

Numerous firms will show **oscilloscopes**, including Telco, whose range includes the Megascope, having a 17 in rectangular tube and producing a high-intensity trace, visible at a distance to a number of viewers simultaneously. Recording oscilloscopes will be found on the stands of Telec and Southern Instruments. High-speed **direct-writing recorders** range from the light-weight Telcograph by Telco, to more sophisticated instruments by Texas Instruments (on the Lindqvist stand) and Honeywell. Honeywell's Visicorder is available with as many as 36 channels, and claims to record at frequencies up to 5000 c/s. Portable high-speed **temperature recorders** will be exhibited by Ateliers Legrand.

A selection of **electrical test meters** will be found at the Metrix stand, and both Metrix and Ferisol are showing valve voltmeters with advanced specifications. A **wave-form analyser** for frequencies between 2·7 c/s and 110 c/s will be exhibited by Sexta. Lindqvist will show the Texas Instruments' **tunnel-diode curve tracer**. Texas claim that this is the only curve tracer available which can test the curve characteristics of all tunnel-diodes now on the market. A new type of electrical bridge for **measuring dielectric constants** will be presented by Tettex. This apparatus replaces the classical Schering bridge, and has been developed for measuring the characteristics of both liquid and solid insulating materials. Tettex are also introducing a new a.c. test apparatus for checking electrical measuring devices, for which an accuracy of better than 0·05% on current, e.m.f. and power measurements is claimed.







Top left: high-speed digital printer (Soler). Top right: range of twelve-stage photomultipliers (Carl Zeiss). Bottom: strain-gauge torque meter (Sexta)

Data processing

Much of the equipment in this section is of American origin. A Ramo-Wooldridge RW 300 **digital computer** will be demonstrated by C.E.A., controlling a model of a power station. Ramo-Wooldridge printout equipment will also be on show. Ampex will exhibit their wide-band **magnetic tape system,** which has a frequency response from 10 c/s to 4 Mc/s. There appears to be no British representation in the large-size computer field, though the de Havilland Anatrol will be on the Newtec stand, and Wayne Kerr will have their own stand where, *inter alia,* their **transfer function computer** will be on show.

The major exhibitor of equipment of French origin in the computer field appears to be S.E.A., who will show a 24-amplifier **analogue computer,** and a range of components and peripheral equipment. This includes tape punches and readers, magnetic-drum memory stores, optical encoders and digital voltmeters. A new **data handling system** will be presented by T.R.T. The inputs to this system may be analogue or digital. Transmission is by pulse-modulated carrier, and a variety of receiving devices may be used. Overall guaranteed accuracy, under specified conditions, is 1%.

Said to be the first of its type to be produced in Europe, a **digital printer** which decodes and prints at five lines/s from a binary-decimal input will be presented by Soler.

Components and accessories

In the field of primary measuring elements, Budd Metalfilm **strain gauges** on the Bufra stand should attract attention. These gauges are approximately 0·00015 in thick, and can be rapidly cemented to the stressed part. S.A.C.M. will show Peltier-effect **cooling elements** and a range of piezo-electric ceramics.

Metrobel will be showing their 'dielectric amplifiers', based on capacitors incorporating dielectrics with characteristics depending on the applied voltage. On the S.E.A. stand will be the Logimag **solid-state switching** device, and L.E.G.P.A. will show an ultra-sensitive solid-state relay which will control up to 10 W for an input of less than one microwatt. Other switching devices of interest can be seen on the S.C.AP. stand, including a magnetic switch with contacts sealed in an envelope of inert gas. Miniature **galvanometric relays** by Albert le Boeuf may be operated by as little as 0·15μW, and control up to 30mW in a purely resistive circuit.

Carl Zeiss will show a range of **photomultipliers** with front cathodes, for photometry and scintillation measuring purposes. The Zeiss stand will also include a number of precision electromechanical devices, including magnetic-clutch couplings and a precision potentiometer. A wide range of **power-switching tubes** to be exhibited by Cerberus will include a recently introduced model for controlling powers up to several kV.

Koenig Automation will present a new hydraulic-pneumatic pressure converter, in which special measures have been taken to obviate the effects of fluid leakage.

Amongst a wide range of electronic units on the Sud Aviation stand will be found an **electronic commutating switch** which can accept up to 64 circuits and operate at speeds up to 10,000 points/s.

Miscellaneous equipment

Instruments associated with the nuclear industry will be well represented. Visitors to the stand of l'Electronique Appliquée will be able to see a number of experiments concerned with the counting and recording of the **activity of nuclear sources.** S.A.C.M. will show a number of **ionization chambers** for measuring the activities of both solids and gases.

Various **nucleonic thickness gauges** will be shown by Mesco and Ekco Electronics. The Ekco exhibits will be on the Jouan stand and will include their new **secondary X-ray gauge.** This gauge extends the possible range of measurement beyond the normal limits of beta-ray instruments, and can be used to determine thickness during the continuous production of metals up to 0·5 in thick. Another X-ray thickness gauge, developed especially for rapid measurements of sheet steel, will be shown by Merline and Gerin. It has been used in an automatic sheet-sorting installation.

Amongst the physical instruments, the **nuclear-track measuring microscope** of Carl Zeiss may arouse interest. This is a high-performance scatter-measuring instrument. The number of instruments concerned with measuring **weather conditions** is surprising, amongst the more interesting being the Jules Richard ice-warning system, and an automatic weather station by the Société Industrielle de Télécommande et de Télémécanique. The station measures barometric pressure, windspeed and direction, humidity, and rainfall, and transmits information by radio.

Voice-frequency **telecommunications equipment,** for remote control applications, will be shown by Télétransmissions Electroniques. S.A.R.E.G. will exhibit a 'talking tele-indicator', designed to give, on demand by telephone, remote verbal readings of a variable. This battery-operated equipment includes a memory-unit, and gives, in addition to the actual reading, ten previous readings taken at predetermined intervals. The sole Hungarian exhibitor, Metrimpex, will show a **microwave measuring receiver** and microwave test equipment.

NAMES OF MANUFACTURERS

Many French firms are known by both their full and abbreviated titles. Where such firms have been mentioned in the preview, the abbreviated form has been used. To avoid confusion, a list of abbreviated and full titles of the firms mentioned is given below:

A.M.E.P.	L'Appareillage Mécanique, Electrique & Plastique
A.O.I.P.	Association des Ouvriers en Instruments de Précision
C.E.A.	Compagnie Européenne d'Automatisme Electronique
C.D.C.	Compagnie des Compteurs
C.R.C.	Constructions Radioélectriques et Electroniques du Centre
D.A.M.	Société pour la Diffusion d'Appareils de Mesure et de Contrôle
L.E.G.P.A.	Les Laboratoires de Physique Appliquée
Manurhin	Manufacture de Machines du Haut-Rhin
M.E.C.I.	Matériel Electrique de Contrôle et Industriel
O.S.I.	Omnium Scientifique et Industriel de France
S.A.C.M.	Société Alsacienne de Constructions Mécaniques
S.A.G.E.M.	Société d'Applications Générales d'Electricité et de Mécanique
S.A.R.E.G.	Société d'Applications Radio-Electrique Garreau
S.C.AP.	Société de Construction d'Appareillage
S.E.A.	Société d'Electronique et d'Automatisme
Sofranel	Société Française d'Electrophysique
Soler	Société Lamy d'Etudes et de Recherches
T.R.T.	Télécommunications Radioélectriques et Téléphoniques
V.M.D.I.	Le Vide Moléculaire dans l'Industrie

CONTROL 20 SURVEY

Closed-circuit television

by **R. F. ROACH** M.B.E., A.M.I.E.E., A.M.Brit.I.R.E.
U.K.A.E.A.

FROM OPERAS TO OPERATIONS, INSTRUments to instrumentalists, all may come under the watchful eye of the closed-circuit television camera. The great variety of uses to which the various manufacturers' systems have been put, and the direct financial saving and greatly increased efficiency that the introduction of a closed-circuit television system may bring, make it surprising that there are not, as yet, more users of this equipment. It could be that many would-be users, when thinking of television, envisage studios and banks of electronic equipment with skilled engineers and camera operators in constant attendance, or think that the cost of the equipment and the installation charges will be beyond their reach. None of these ideas is justified because all the systems on the British market are simple to install and no one more skilled than the average television-set user is required to operate them, and the reliability of the equipments is comparable to that of a domestic receiver.

The costs of the various systems vary according to design, construction for working in special locations, and the supply of optional accessories, and may be high. Most firms, however, are already spending as much or more on office and works equipment without obtaining anything like the financial and efficiency improvements that the same expenditure on a television system would bring.

The systems available range from the simple to the complex. The simple closed-circuit television system (Fig. 1) consists of a *camera unit* (C.U.), a length of standard coaxial cable, such as is used between the aerial and the domestic television receiver, and a standard commercial receiver. The camera unit is entirely self-contained. The mains cable is fed into it and, since the whole unit has a power consumption of only a few watts, any 5 A supply is all that is required. The unit is compact and normally weighs only a few pounds, and can easily be mounted inconspicuously and in a confined space. It is undesirable, for technical reasons, to mount the camera in a vertical, or near-vertical, plane, and so sometimes a mirror system may have to be used. The output from the unit is an r.f. signal which is fed to the receivers *via* a 75Ω coaxial cable. Since the r.f. signal is usually within Band I, any commercial receiver may be used to receive the transmitted picture. Systems vary, but several receivers may be fed from one camera unit at the same time, the distance between the camera unit and the receivers being governed by the manufacturer's design, definition, and the number of receivers to be used.

The more complex equipment has a much wider range of uses and a typical system (Fig. 2) is described below.

It consists of three units in the camera chain instead of the one in the simple system. The *camera head* (C.H.) is very small, and little more than the pick-up tube, control mechanisms, and an amplifier. Some distance away, and connected to the camera head by a multi-core cable, is the *camera control unit* (C.C.U.). This unit contains most of the electronics of the system and the various adjustment controls, and is connected to the mains supply. It can be either portable or constructed for mounting in a standard Post Office type of rack, and may weigh in the region of thirty pounds. The use of the control unit allows the camera head to be smaller than would otherwise be possible, to be mounted in locations where because of temperature and other external disturbances it would be difficult

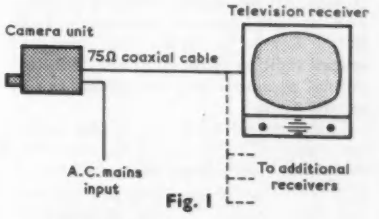


Fig. 1

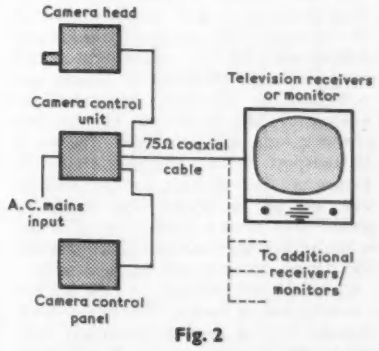


Fig. 2

or impossible to mount electronic equipment of standard design, or where it is not possible for a man to carry out adjustments such as focusing when the equipment is in operation (e.g. the inside of a nuclear reactor.) The third item in the camera chain is the *camera control panel* (C.C.P.) which is a remote

switching and control panel situated at a distance from the control unit and connected to it by means of a multi-core cable. From the control panel many control functions can be exercised, some typical examples being described in the following paragraph.

The camera head might be mounted in a splashproof case with a glass observation window kept clear by means of a windscreen wiper, the whole unit being mounted on a pan-and-tilt table. The camera head might well be fitted with a zoom lens or a multi-turret lens-mount with remote focusing and an iris control attachment. From the control panel these various devices could be controlled to enable a very wide range of views to be obtained at the viewing points. Also it is possible to switch between cameras in a multiple system to obtain other views. The connexion between the units in the camera chain and the viewing equipment is by means of 75 Ω coaxial cable up to certain limits of distance depending on the manufacturer's design and the number of receivers used. The system can have either an r.f. output in Band I or a video-signal output. When equipment with an r.f. signal output is used any commercial receiver (Rx) may be used, but by using video-signal output equipments it is possible to obtain higher definition at the monitor (M). For video-signal systems special video monitors have to be used.

Both the simple and the more complex systems can have the separation between camera units and receivers/monitors increased, and also the number of receivers/monitors increased, by the inclusion in the camera–receiver/monitor link of amplifiers or centimetric radio links. For most systems and uses, no special lighting is required and therefore normal processes and movements can be viewed easily.

Closed-circuit television is now within the reach of most companies, enabling equipment, instruments and processes to be seen in operation where previously it was not possible because of inaccessibility or danger to life: control engineers can oversee many remote locations and indications from one centralized control position; large numbers of people can now see in close-up demonstrations which previously could only be described to them; more efficient use can be made of transport systems and traffic control; documents and records can be centralized, and yet on instant view at distant points, thus saving duplication of effort in record keeping and costly accommodation space; security can be increased.

Closed-circuit television is now neither a novelty nor a luxury. For the control engineer it is a powerful auxiliary tool which enables him to see for himself distant operations, view whole panels of instruments at many remote locations, and look into places previously closed to him because of space limitations and ambient conditions. For him it shortens the time cycle between cause and cure and, through better control, increases efficiency.

CLOSED CIRCUIT TELEVISION SYSTEMS

MANUFACTURER	MODEL	UNITS IN CAMERA CHAIN	DIMENSIONS (INCHES) AND WEIGHT (POUNDS) OF UNITS IN CAMERA CHAIN	BASIC CAMERA DATA	POWER SUPPLY AND LOAD	PICTURE SYSTEMS AVAILABLE (LINES)	TRANSMITTED DEFINITION (LINES)	SPACING BETWEEN UNITS (FT)	PICTURE TRANSMISSION SYSTEM	NO. OF RECEIVERS/ MONITORS (WITHOUT ADDITIONAL AMPLIFIERS)	SUBJECT ILLUMINATION (a) MINIMUM (b) DESIRABLE (FT CANDLES)	LENS MOUNTS	RECEIVERS/MONITORS
Airmec (A.C.E.C.)	6004	1	C.U. 5½ × 8½ × 12½ 14½	1in Vidicon	220V, 50c/s, 45W	625	600	C.U.–M 1650	video	1	(a) 4·5 (b) 14	16mm 'D' mount	8in type 6052 17in type 6050
	★501												
Beulah Electronics	D800	1	C.U. 6 × 7 × 12 14	1in Vidicon	100–125V, 200–250V, 50c/s, 60W	405 625	400	C.U.–Rx/M 3000	r.f. or video	20	Normal room lighting	16 mm 'C' mount	Television receiver or 17in monitor
	★502												
	D805	1	C.U. 6 × 7 × 12 14	1in Vidicon	110–125V, 200–250V, 50c/s, 60W	405 625	550	C.U.–M 3000	video	12	Normal room lighting	16mm 'C' mount	17in monitor
	★503												
E.M.I. Electronics	Mk 6	2	C.H.* 4 × 7 × 12 16 C.C.U. 19 × 8½ × 19 65	1in Vidicon	110–115V, 195–255V, 50c/s, 300W	405 525 625	650	C.H.–C.C.U. up to 1000 C.C.U.–Rx 2500 C.C.U.–M 1000	r.f. video	15 20	(a) 1 (b) 20	16mm 'C' mount	Television receiver or 14in monitor TPM6/14A 17in monitor TPM6/17A
	★504												
Epsylon Industries	CCV1	2	C.H. 5 × 4½ × 10½ 8 C.C.U. 21½ × 16½ × 10½ 46	1in Vidicon	95–125V, 190–250V, 50 or 60c/s, 200VA	405 525 625	650	C.H.–C.C.U. 300 C.C.U.–M 3000	video	6	(a) 5 (b) 20	Broadcast or 'C' mount	8, 14, 17, 21, 24in monitors Black/white short persistence or orange long persistence
	★505												
	FA10	2	C.H. 3½ × 6 × 8½ 6½ C.C.U. 9½ × 15½ × 21½ 55	PTW 1in Resistron	110 or 220V, 50c/s, 220VA	625	400	C.H.–C.C.U. 525 C.C.U.–Rx 4000 C.C.U.–M 1000	r.f. or video	several hundred: (o/p: 4V across 150Ω)	(a) >½ (b) 1	16mm 'C' mount	Television receiver or 7, 14, 17, 21in monitors
	★506												
Grundig (Great Britain)	FA10 Miniature	2	C.H. 2½ dia. × 5½ 1 C.C.U. 9½ × 15½ × 21½ 55 Adaptor 6½ × 9½ × 21½ 22	PTW ½in Resistron	110 or 220V, 50c/s, 220VA	625	300	C.H.–C.C.U. 525 C.C.U.–Rx 4000 C.C.U.–M 1000	r.f. or video	several hundred: (o/p: 4V across 150Ω)	(a) >½ (b) 2	8mm	Television receiver or 7, 14, 17, 21in monitors
	★507												
	FA40	2	C.U. 5½ × 7 × 11½ 11 Power supply 6 × 12 × 8 12	PTW 1in Resistron	110 or 220V, 50–60c/s, 100VA	625	400	C.H.–P.S.U.‡ unlimited C.U.–Rx 3000	r.f.	25	(a) 1 (b) 4	16mm 'C' mount	Television receiver
	★508												
Hasler	Vistarama	3	C.H. 4½ × 5½ × 8½ 6½ C.C.U. 5½ × 15 × 19½ 40 C.C.P.	1in Vidicon	110–127V, 200–250V, 220VA	405 525 625	600	C.H.–C.C.U. 25 C.C.U.–M 3000	video	10	(a) 5 (b) 20	16mm 'C' mount	9½, 14, 17, 21, and 24in monitors
	★509												

	✱508	2	Power supply 6×6½×8 12	PTW 1in Resistron	110 or 220V, 50c/s, 100VA	625	400	C.H.–P.S.U.‡ unlimited C.U.–Rx 3000	r.f.	25	(a) 1 (b) 4	16mm 'C' mount	Television receiver
Heslop	Vistarama ✱509	3	C.H. 4½×5½×8½ 6½ C.C.U. 5½×15×19½ 40 C.C.P. 7×3×5 2	1in Vidicon	110–127V, 200–250V, 220VA	405 525 625	600	C.H.–C.C.U. 25 C.C.U.–M 3000	video	10	(a) 5 (b) 20	16mm 'C' mount	8½, 14, 17, 21, and 24in monitors
Marconi's Wireless Telegraph Company	BD871 ✱510	2	C.H. 4 dia.×11 7 C.C.U.† 9¼×14½×19¼ 45	1in Vidicon	100–125V, 200–250V, 50 to 60c/s, 200VA	405 525 625	650	C.H.–C.C.U. 1000 C.C.U.–C.C.P. 500 C.C.U.–Rx/M 1000	r.f. or video	depends on length of cables	(a) 10 (b) 50	16mm 'C' mount	Television receiver or 8½, 14, and 21in monitors
Nash and Thompson	Mk 1 ✱511	1	C.U. 7½×7½×13½ 16	1in Vidicon	200–240V, 50c/s, 50W	405 (625)	300	C.U.–1 Rx 2500 C.U.–6 Rx 1000	r.f.	14	Normal room lighting	16mm 'C' mount	Television receiver
Nottingham Electronic Valve	NEV EYE ✱512	1	C.U. 11½×5½×6½ 12	PTW 1in Resistron	200–250V, 50c/s, 50W	405 625	300	C.U.–Rx 1500	r.f.	3	(a) 2 (b) 20	16mm 'C' mount	Television receiver
Peto Scott Electrical Instruments	TI406 ✱513	2	C.H. 5½×5½×10½ 9½ C.C.U. 18½×18×10 30½	1in Vidicon	95–125V, 190–250V, 50 or 60c/s, 180VA	405 525 625	650	C.H.–C.C.U. 300 C.C.U.–M 1000	video	12	(a) 5–10 (b) 20	16mm 'C' mount or std. broadcast	8in type TB 1204 14in type TB 1203 17in type TB 1201 21in type TB 1202
Philips Electrical	EL5730–EL5748 ✱514	2	C.H. 4½×6½×11½ 9½ C.C.U. 17½×12½×21½ 80	1in Vidicon	110, 125, 145, 200, 220, 245V, 50 or 60c/s, 300W	525 625	600	C.H.–C.C.U. 500 C.C.U.–Rx/M Depends on number of Rx/M	r.f. or video	5	(a) 1 (b) 20	16mm 'C' mount	Television receiver or 14in videomonitor type EL5749/30
Pye T.V.T.	Mk IV ✱515	3	C.H. 5 dia.×11 7 C.C.U. 6½×16×19 34 C.C.P. 9×5½×6 6½	Staticon C.932	90–260V, 40 to 60c/s, 180VA	405 525 625	600	C.H.–C.C.U. 1000 C.C.U.–C.C.P. 3000 C.C.U.–Rx/M 3000	r.f. or video	8	(a) 5–10 (b) 25	16mm 'C' mount	Television receiver or 8½, 14, 21, and 27in monitors
Rank Precision Industries	63–A ✱516	1	C.U. 5 1/16×6 11/16×9⅛ 10	1in Vidicon	105–125V, 50c/s, 50W	625	400	C.U.–M 2500	video	30	(a) 5 (b) 20	16mm 'C' mount	8, 14, 17, 21, 23, 24in monitors, and large screen projectors. (101–AF television receivers or monitors).
	70–B ✱517	1	C.U. 5 1/16×7⅛×11 1/16 12	1in Vidicon	105–125V, 50c/s, 45W	625	600	C.U.–M 2500	video	30	(a) 5 (b) 20	16mm 'C' mount	
	101–AF ✱518	1	C.U. 4⅛×9½×14 18	1in Vidicon	105–125V, 50c/s, 125W	625	450	C.U.–Rx/M 2500	r.f. or video	30	(a) 10 (b) 50	16mm 'C' mount	
	RGS–10 ✱519	2	C.H. 7 dia.×16 15 C.C.U. 7×19×11 27	1in Vidicon	110V, 50, 60, 400c/s, 15W	525 625	700	C.H.–C.C.U. 2000 C.C.U.–M 2500	video	30	(a) >1 (b) 10	16mm 'C' mount	
	320BV ✱520	2	C.U. 7½×12×18½ C.C.U. 3 alternatives	Broadcast Vidicon	105–125V, 50c/s Load depends on C.C.U. used	625	700	C.H.–C.C.U. 1000 C.C.U.–M depends on C.C.U. used	video	30	(a) 5 (b) 20	16mm 'C' mount	
	333 ✱521	1	C.U. 2½×6⅛×8 4	1in Vidicon	105–125V, 50 to 1000c/s, 10W	525 625	600	C.U.–M 4000	video	30	(a) 5 (b) 20	16mm 'C' mount	
	I.O.–11 ✱522	2	C.H. 5×5×20 12 C.C.U. 14½×4½×18	Image Orthicon	110 and 220V, 50 or 60c/s, 100W	625	600	C.H.–C.C.U. 100 C.C.U.–M 2500	video	30	(a) 0·1 (b) 10	Stock I.O. 35mm	

* Minicamera 3in dia. × 9in; weight 6 pounds † The C.C.U. has a built-in 20Mc/s oscillator to provide carrier: then C.C.U.–M. spacing is 1 mile. ‡ Power Supply Unit.

★ For further information, circle the appropriate number on reader reply card facing page 162.

A monthly review—under basic headings—of the latest control engineering developments for all industries; especially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to SERVO-MOTORS

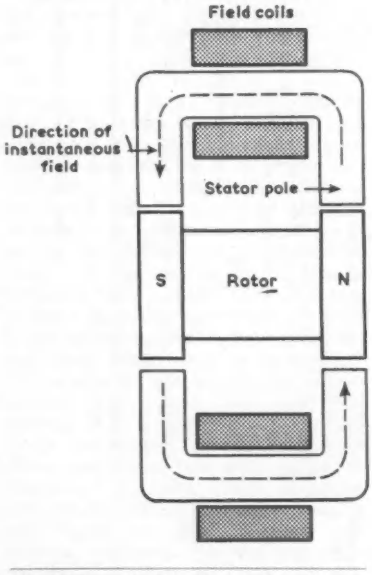
Low-speed a.c. motor

Conventional forms of electric motor normally run at speeds which are too high for many purposes, and reduction gears usually have to be employed. A radically new type of motor—the Rosain–Schterbatcheff motor—now being manufactured by S.F.A.I.R.E.,* gives output-shaft speeds of between 10 and 100 rev/min. The actual running speed depends on the relative dimensions of parts of the mechanism, and is claimed to be constant within ±1 rev/min for a given motor.

Basically, the motor comprises a cylindrical bearing-less rotor which moves with a rolling motion inside a cylindrical stator. The stator coils are wound to provide a rotating magnetic field, and the rotor is permanently magnetized along its axis. Fig. 1.1 shows a schematic cross-section; it will be noted that the field produced by the stator windings is such that both ends of the rotor are simultaneously attracted to the same side of the stator cavity. The point of attraction between rotor and stator thus revolves round the inner surface of the stator, at the same speed of rotation as the field.

> This month we describe some of the more unconventional items which will be on show at the Mesucora exhibition, which takes place in Paris, 9 to 17 May inclusive.

Fig. 1.1 Schematic cross-section of motor. The field rotates as in a conventional induction motor, except that there is always a 180° phase difference between the direction of the field at opposite ends of the rotor



* Société Française d'Applications Industrielles et Rurales de l'Electricité

The principle of operation may be seen from Fig. 1.2. As with a conventional synchronous motor, the field coils are wound to produce a radial field with a rate of rotation equal to the supply frequency. Under the influence of this field, the magnetized rotor rolls round the inner surface of the stator. In doing so, there is a slow rotation of the rotor relative to its own centre, in a sense opposite to that of the field rotation. This can be seen by considering the movement of the rotor during one revolution of the field. Suppose at a given instant contact is being made between the point P on the stator and the point A on the rotor. After one revolution of the field, contact will again be made at P, but owing to the difference in circumference between the rotor and the track on which it rolls, A will be at some point A_1 at this time. The length of the arc AA_1, assuming there is no slipping, is $2\pi(R - r)$, where R and r are the radii of the stator cavity and the rotor respectively. Thus the rotor rotates through an angle of $2\pi(R - r)/r$, in a clockwise direction, during one cycle of the electrical supply; i.e. the rotor revolves at $(R - r)f/r$ rev/s, where f is the supply frequency. This motion represents the useful output from the motor. The actual motion of the rotor, however, contains another component. The actual path traced out

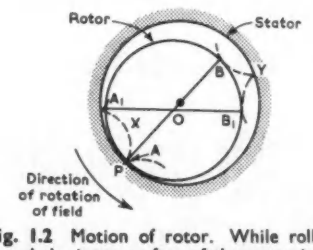


Fig. 1.2 Motion of rotor. While rolling round the inner surface of the stator in an anti-clockwise direction, the rotor revolves at a relatively slow speed about its own axis in a clockwise direction

by A during one revolution of the field is AXA_1, and the path traced out by the other end of the diameter is BYB_1. The complete motion of the rotor may thus

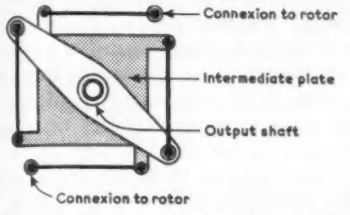


Fig. 1.3 Coupling for damping out the unwanted (vibratory) component of motor output

be regarded as a rotation about its own centre at the frequency given above, plus vibration at the supply frequency. The latter motion is unwanted, and has to be damped out by the use of a suitable coupling. The coupling normally used by S.F.A.I.R.E. is shown in Fig. 1.3; simpler types of coupling may be used in certain applications.

In practice, the rolling surfaces are disks fixed to the ends of the rotor

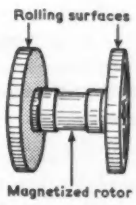
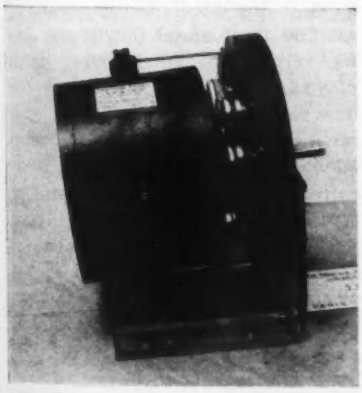


Fig. 1.4 Form of complete rotor assembly

(Fig. 1.4) running in tracks in the motor body, so that the rotor and stator can be of standard size for different output speeds.

Apart from its low speed of rotation, a particular advantage claimed for the Rosain–Schterbatcheff motor is the speed with which it can be started, stopped, and reversed. For the model at present in production, the response time is quoted as less than 0·01 s, and the reversal time (which is achieved by reversing the field connexions) is of the same order of magnitude. This initial production model is produced for a range of speeds between 10 and 100 rev/min, and has a nominal maximum torque of 400 ozf in. (The actual maximum available torque is related to the dimensions of the rolling surfaces, i.e. to the speed for which the motor is designed.) A further advantage of this type of motor is that maintenance is not required, there being no bearings or commutator.

Fig. 1.5 Low-speed motor with coupling attached



. . . to ACTUATION

Electrically controlled valve with inert-gas actuator

Most electrical process control schemes use pneumatically or hydraulically operated control valves, some form of converter and amplifier being required to produce fluid power from the electric control signal. Hydraulically operated valves are satisfactory for most applications, but are usually complex and expensive, because of the precision required in the manufacture of the mechanical parts. Pneumatic valves, though also generally satisfactory in performance, have the disadvantage that both electrical and pneumatic supplies are required at the valve. An air compressor, and suitable equipment for filtering and drying the air, have to be provided. The use of electropneumatic valves may thus prove expensive where the air supply is used only for a small number of valves, or where the valves are widely dispersed. As a result of these drawbacks, the growing popularity of electrical control systems has been accompanied by a renewed interest in control valves requiring only an electrical supply.

Valves at present available in this category (other than electrohydraulic valves) fall into two classes: (1) those using motors and gearing to operate the valve, and (2) thermo-electric types. The first category is not always satisfactory where high speed of response is required, because of the unavoidably high inertia of the operating mechanism. In the second category, power is controlled by varying the pressure of a vapour generated from a liquid contained in the actuator. Pressure variations may be obtained by applying a constant electrical heat-input to the liquid, and controlling the rate of escape of the vapour from the pressurized area to a condenser, or by controlling the heat input. The thermo-electric actuator has not yet achieved wide popularity, possibly because it involves a relatively large continuous energy wastage in the form of heat loss. This is particularly true in large valves, where the ratio of thrust developed to electrical power input is unfavourable.

A new solution to the problem of valve actuation is offered by the patented 'Auto-pneumatique' system developed jointly by the French firms A.D.A.R. and Société des Usines Chausson. Basically, the method used is to incorporate a small electrically-driven compressor in the actuator,

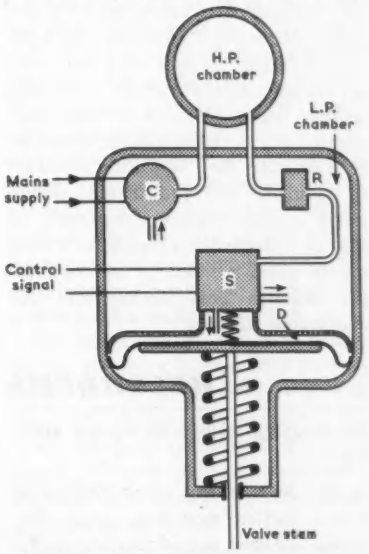


Fig. 2.1 Schematic diagram of electrically controlled inert-gas valve-actuation system

which supplies pressurized inert gas to operate the valve. Gas is bled in or out of the valve diaphragm-chamber, as required, whenever the valve stem position does not correspond to that demanded by the electrical control signal.

The principle of the A.D.A.R. valve actuator is shown in Fig 2.1. A gas-tight chamber, containing low-pressure inert gas, such as nitrogen, encloses all the active components of the system. A compressor, C, draws its supply from this l.p. chamber and delivers to an h.p. chamber, which is equipped with a pressure-switch to stop the compressor when the required pressure is reached. The h.p. chamber supplies the positioning relay S *via* a pressure reducer R, so that a constant-

pressure supply is always available at *S*. Any difference between the actual valve-stem position and the position called for by the controller causes *S* to take the necessary corrective action. Gas is fed into *D*, or bled from *D* into the l.p. chamber, as required. The relay *S* works on the conventional principle of balancing a magnetic force, developed by the control signal, against a spring tension dependent on the valve-stem position. The difference is detected by a flapper-nozzle system controlling a pneumatic relay in the usual way.

The performance of the system should, in general, be similar to that of conventional pneumatic valve-positioners. Besides requiring no pneumatic supply, it has the advantage that all working parts are sealed in a gas-tight, flame-proof chamber. In addition, a supply failure does not cause an immediate failure of the valve, protection being provided by the compressed gas stored in the h.p. chamber. It is claimed that very little attention is required—the pressurized system being in this respect comparable to that of a domestic refrigerator. Power consumption is small, as the compressor requires only about 60W for continuous running.

. . . to RECORDERS

Strain-gauge bridge to rep'ace slide-wire

In the development of self-balancing potentiometric recorders, much emphasis has been placed recently on the problem of replacing the conventional slide-wire.* The arrangement of a toroidal coil and sliding contact has been standard for this type of recorder for many years, and if properly designed and constructed need give very little trouble. However, the contact must ultimately wear, and there is always the possibility of dirt causing faulty contact and subsequent error. Resolution is also limited to that represented by the potential step caused by the slider moving from one coil of the slide-wire to the next.

The new Honeywell Electronik 17 recorder uses a strain-gauge bridge in place of the conventional slide-wire. This arrangement involves no moving contacts, and has the further advantage that its resolution is theoretically infinite. The device, christened the Stranducer by Honeywell, is shown schematically in Fig. 3.1. It is similar to the conventional arrangement in that the Stranducer, like the slide-wire unit, produces a e.m.f. equal and opposite to the input e.m.f. Any out-of-balance between these two e.m.f.'s

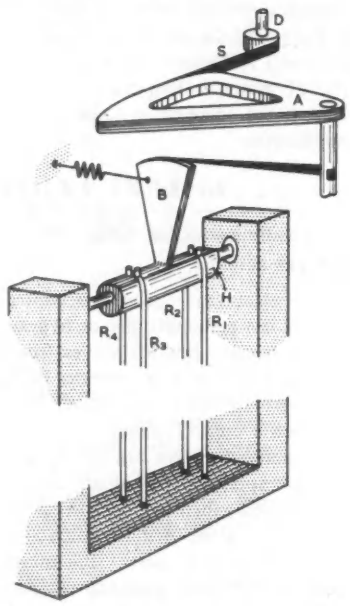


Fig. 3.1 Schematic diagram showing the principle of the Stranducer strain-gauge bridge

is amplified and used to drive a balancing motor in the appropriate direction. This motor moves the indicating and recording mechanism to the new balance position, and also drives the shaft *D* to adjust the output from the Stranducer (Fig. 3.1). *D* is connected to the quadrant *A* by the flexible strip *S*, and a similar drive is used to transmit the resulting movement of *A* to the arm *B*. The assembly comprising *B* and the hub *H* is thus caused to rotate through a small angle for a relatively large rotation of the shaft *D*, without backlash errors. The ends of the resistance wires R_1, R_2, R_3, R_4 are pinned to the hub *H*, so that a given rotation of *H* increases the tension in two of the wires and decreases the tension in the other two.

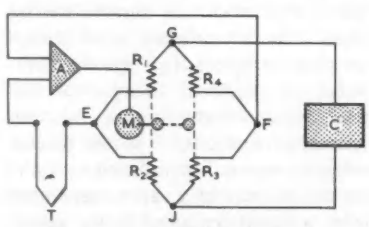


Fig. 3.2 Basic electrical connexions to the strain-gauge bridge

The resistance wires (or strain-gauges) are connected in the form of a Wheatstone bridge as shown in Fig. 3.2, the bridge being supplied from a source of constant current, *C*. It will be noted from the diagrams that the tensions in the wires R_1 and R_3 increase together, with corresponding decreases in the tensions in R_2 and R_4, and *vice versa*. Thus the total resistance of the bridge between *G* and *J* does not change when it is unbalanced, though a potential difference is developed between *E* and *F*.

As previously stated, the e.m.f. developed between *E* and *F* at balance point is equal and opposite to the input e.m.f. (represented by the thermocouple *T* in Fig. 3.2). As for the conventional type of recorder, resistances may be added to the circuit to give the required range and zero.

. . . to FLOW

Thermo-electric method for measuring small flow-rates

Thermo-electric devices for detecting very small gas-flows are not uncommon; such devices are found in a number of gas-analysis instruments, where their purpose is usually to detect a state of unbalance in a bridge network through which the gas to be analysed is flowing (e.g., certain types of 'magnetic wind' oxygen analysers). The gas flow through the thermal detector in such instruments is usually limited to a flow-rate of a few hundred cm^3/h.

The idea of a thermal device for flow measurement has been developed by the Société D.A.M.† in the form of a meter for direct measurements of gas flow up to about 16 l/h, and also for very small liquid flows. It is pointed out by the makers that the flow range can be extended by connecting the meter across an orifice plate—i.e. by using it as an alternative to a normal differential-pressure type instrument.

The measuring unit, which is known as the 'micro flowmeter', is shown schematically in Fig 4.1. The fluid to be metered flows through the central

* A description of the conventional arrangement, and of one recently-introduced substitute for it, appeared in *Ideas Applied* on p. 106 of our January 1961 issue.

† Société pour la Diffusion d'Appareils de Mesure et de Contrôle.

tube, which in the standard model is made of either stainless steel or nickel. Around this tube three coils are wound, the central coil being a heating element, and the other two being temperature-sensitive platinum resistances. The platinum resistances are connected into a bridge circuit, in which the other resistances are of manganin. When there is no flow in the central tube, there is equal transfer of heat to the two platinum coils, and the bridge is balanced. Movement of the fluid causes unsymmetrical heat transfer, so that the resistance of one platinum coil is increased while that of the other is reduced. This effect is proportional to the mass of fluid passing and to its specific heat. The resulting output from the bridge circuit, which is within the range 0–100 mV, may be taken to any conventional millivolt recorder.

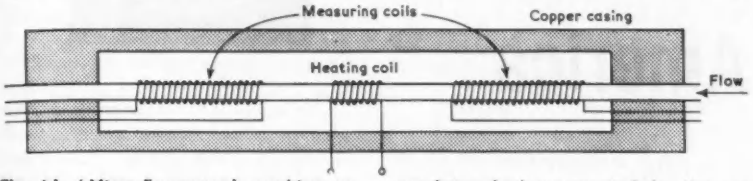
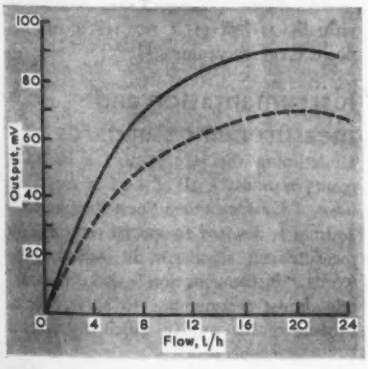


Fig. 4.1 'Micro-flowmeter', working on thermo-electric principle

A typical relationship between output and flow is shown in Fig 4.2. These curves were obtained with a hydrogen–oxygen gas mixture, the two different curves representing flow tubes of different materials. It will be noted that the characteristic is nearly linear at the lower flows, but that the sensitivity decreases rapidly at higher flows. Modifications may be made to the standard design to extend the linear portion of the response up to a flow-rate of 12 litre/h. The accuracy claimed by the makers for the standard measuring element is $\pm 5\,cm^3/h$ for flow-rates up to $500\,cm^3/h$, and $\pm 1\%$ for higher flow-rates within the useful range of the meter. The response times required to reach 60% of the true flow are given as 30 s and 50 s for the nickel-tube and steel-tube models respectively. Accuracy is dependent on the stability of the electrical supply, which can be from either a.c. mains or battery. A voltage regulator is incorporated in the apparatus when it is supplied for use with a.c. mains.

Fig. 4.2 Output curves from 'micro-flowmeter'. The upper curve was obtained using a stainless steel flow-tube and the lower using a nickel flow-tube



The 'micro flowmeter', when used as a detector of the differential pressure developed across an orifice plate, might have advantages over conventional forms of detector in some applications, such as those where the fluid has to be maintained above ambient temperature. For example, a hot gas which would condense at ambient temperature would call for special measures in a system incorporating connecting pipes containing effectively static fluid; in the 'micro flowmeter', the fluid is in continuous motion, and no difficulty should be experienced in keeping it in the gaseous state in such an application. The upper limit for the fluid temperature is about 60°C for presently available instruments. This restriction is imposed by the temperature limitations on the insulating materials used.

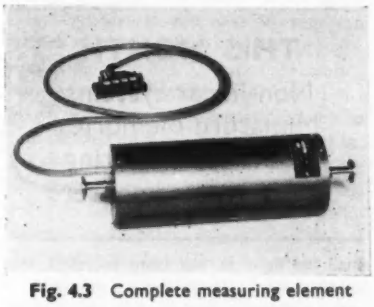


Fig. 4.3 Complete measuring element

. . . to AMPLIFICATION

Photo-electric d.c. amplifier

Many d.c. amplifiers have been made using moving coils for detecting the input, combined with some form of photo-electric device to produce the amplification. A new moving-coil amplifier by La Technique Electronique (Telec) incorporates a number of known techniques in a manner which, according to the makers, overcomes many of the difficulties inherent in the amplification of direct voltages. It differs from most previous instruments of this type in that the actual amplification is performed by a conventional a.c. amplifier.

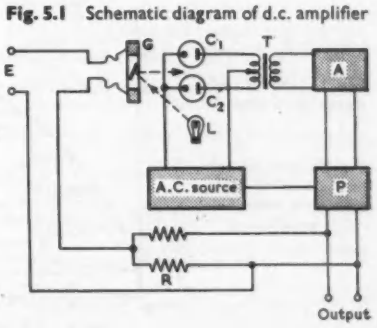
The Telec amplifier is shown schematically in Fig. 5.1. Light from a source L is focused on a mirror carried by the galvanometer coil G, and reflected on to the two photocells C_1 and C_2. The position of G is determined by the difference between the input E and a potential, proportional to the output, developed across the resistance R. When this difference is zero, the two photocells are equally illuminated, and the two inputs to the centre-tapped primary of the transformer T are equal in magnitude but opposite in phase. There is thus no output from the a.c. amplifier A. A change in the input E causes differential illumination of the photocells, and a consequent output from A. This is taken to the phase-sensitive rectifier P (supplied from the same source as T), which produces the output and the feedback voltage.

The frequency of the a.c. supply feeding the input circuit of T is high (1000 c/s) compared to the natural frequency of the galvanometer. The maximum gain obtainable from the system is about 200, and satisfactory response is obtained for input frequencies up to about 16 c/s.

The standard model of this amplifier has an internal input impedance of $850\,\Omega$ and an output resistance of $6\,\Omega$. It is claimed that the zero drift is negligible after an initial warming-up period of a few hours.

A 'submerged' type of galvanometer is used, but it is nevertheless recommended that anti-vibration mountings should be employed.

Fig. 5.1 Schematic diagram of d.c. amplifier



A rapid automatic method of plotting root loci is included in this month's contribution from our special correspondents in the United States

Look at America

Graphical solution of non-linear systems

A simple and useful method for solving non-linear first-order equations has recently been suggested by Miró (*1*), and is very similar to the ' slopeline ' method previously suggested by Paynter (*2*).

For equations of the form

$$a_1 \frac{dC}{dt} + f(C) = R(t)$$

it is possible to write

$$\frac{dt}{a_1} = \frac{dC}{R(t) - f(C)}$$

or in terms of finite differences,

$$\frac{\delta t}{a_1} = \frac{\delta C}{R(t) - f(C)}$$

The angle ϕ is then defined by

$$\tan \phi = \frac{\delta C}{R(t) - f(C)} = \frac{\delta t}{a_1}$$

as shown in Fig. 1. Choosing ϕ to be a small angle allows the approximation

$$\delta C = \frac{R(t) - f(C)}{a_1} \delta t = [R(t) - f(C)]\phi$$

The graphical solution procedure involves choosing a specific time increment δt small enough to ensure that $\delta t/a_1 = \tan \phi \simeq \phi$ when ϕ is a small angle. This is the same as requiring that δt be small compared to the characteristic time of the solution. Then it can be seen in Fig. 1 that δC_1 represents the change in the output variable over the first time interval, and δC_2 is the incremental change over the second time interval. Addition of the incremental changes is automatically made along the C axis, and since the time δt has been specified, the response, $C(t)$, can be directly obtained.

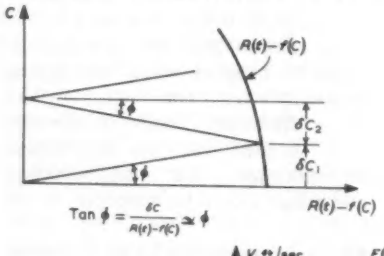
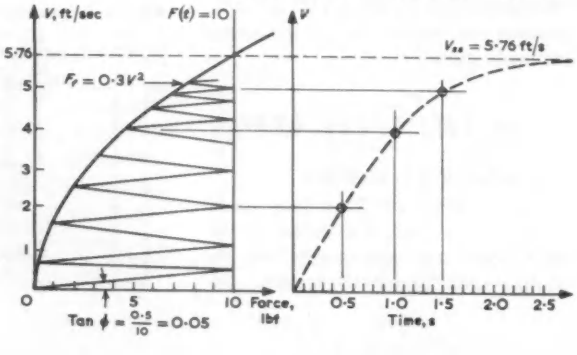


Fig. 1 (above) Definition of ϕ and δC

Fig. 2 (right) Graphical ' slopeline ' solution to a non-linear problem



THIS MONTH

Non-linear systems
Miniature memories
Root locus plotting
Pneumatic computers

As an illustration of the method, consider a mass, $M = 2$ slugs, being accelerated by a constant force of 10 lbf applied at time $t = 0$. A non-linear friction force of $0{\cdot}3\ V^2$ acts on the mass, where V is its velocity. The differential equation of motion is then

$$2 \frac{dV}{dt} + 0{\cdot}3\ V^2 = 10$$

Choosing $t = 0{\cdot}1$ s gives rise to

$$\tan \phi = (0{\cdot}1)/2 = 0{\cdot}05 = \phi$$

Rather than perform the subtraction, $10 - 0{\cdot}3\ V^2$, it is easier to plot each of the terms separately, and draw the ' slopelines ' between them. Fig. 2 describes this simplification and also shows the technique of solution. The method can also be extended to solve second-order equations.

Miniature memory drum

Miniature memory drums, that can spin indefinitely and which can operate reliably under extremely adverse conditions, are under development at the Sperry Gyroscope Co., Great Neck, New York (*3*). Sperry engineers expect that the new memory drums will contribute greatly to future advances in space exploration by making it possible for a computer to perform aloft reliably for years. The use of an air-bearing suspension for the rotor, rather than conventional ball bearings, makes an almost infinite drum life possible.

An eight-pound aluminium spherical drum, which can store information at 600 bits to the inch (or a total of 358,000 bits) is claimed to have six times the capacity of any other unit of its size. To achieve this unusually large storage capacity, ' floating heads ' are used to pick up and record data. Instead of being fixed to the drum assembly, the heads ' float ' on a film of air one ten-thousandth of an inch above the drum's surface.

With most conventional computers using a similar type of memory drum, the drum must complete one revolution before the computer can read the information it wrote into the drum. A unique feature of the new drum is its ' one-word loop ', which enables the computer to utilize information virtually as fast as it receives it and deposits it on the drum.

Instrumentation and measurement standards

Underlining the importance of measurements in industry, all of the February 1961 issue of the Instrument Society of America Journal is devoted to special reporting on measurement standards. In America, the words ' instrumentation ' and ' control ' are almost synonymous to some people, because of the way in which instruments

have evolved with the field of control systems. The articles in this issue stress the needs for better standards of measurement. The activities of the National Bureau of Standards and the role of the I.S.A. are described, and an excellent bibliography on measurement standards is included.

Automatic root locus plotting

Investigation of control system performance by means of the root locus technique is well established. The method provides a graphical representation of system behaviour that is easily understood and readily useful for design purposes, but which suffers from the disadvantage that the procedure for obtaining the root loci is normally tedious. A scheme for mechanizing the procedure

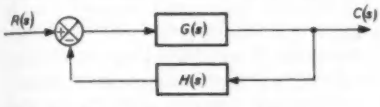


Fig. 3 Generalized control system

with the use of standard computing components is suggested by Liethers, Houpis, and D'Azzo (*4*).

For the generalized control system of Fig. 3,

$$C(s)/R(s) = KG(s)/[1 + KG(s)H(s)]$$

and $$s = \sigma + j\omega$$

The roots of the characteristic equation,

$$1 + KG(s)H(s) = 1 + K\frac{(s - z_1)(s - z_2)\ldots(s - z_w)}{(s - p_1)(s - p_2)\ldots(s - p_v)} = 0$$

determine system behaviour. These are found by applying the two simultaneous conditions:

1. $\angle G(s)H(s) = (1 + 2m)180°$, $m = \pm 1, \pm 2$, etc.
2. $K|G(s)H(s)| = 1$.

The *locus* is obtained by applying only the first condition (called the angle condition). Fig. 4 shows the overall scheme used to satisfy the angle condition automatically. An integrator is placed after the error generation in order to provide a system with zero steady-state error. It is seen that the output of interest is the signal representing s, corresponding to values of $|s|$ arbitrarily chosen over a suitable range. For accurate operation, $|s|$ must be varied slowly compared to the loop dynamics.

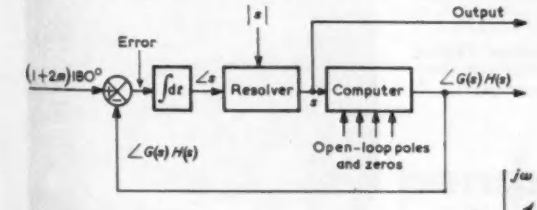


Fig. 4 (left) Functional computing scheme

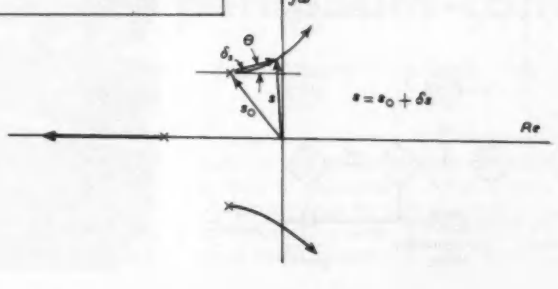


Fig. 5 (right) Definition of s in terms of $s_0 + \delta s$ and the angle θ

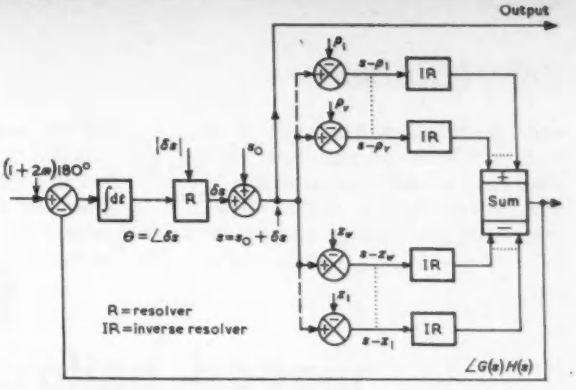


Fig. 6 Detailed computational scheme

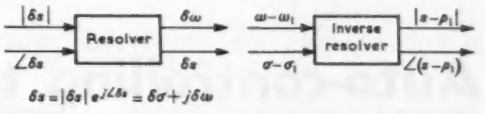


Fig. 7 Input-output characteristics of resolver and inverse resolver

$$\delta s = |\delta s|\, e^{j\angle \delta s} = \delta\sigma + j\delta\omega$$

In order to eliminate problems arising from the fact that loci with multiple branches may require multi-valued solutions for $\angle s$ when $|s|$ is constant, the computational scheme is arranged to plot one branch of a locus at a time. The principle used is shown in Fig. 5, where the vectors s_0 and δs, and the angle θ are defined. For a given branch, s_0 is known and can be set into the computer as a constant. Then when a value for $|\delta s|$ is arbitrarily chosen, the computer finds the value of θ necessary for s to lie on the locus. Figs. 6 and 7 describe in detail how this is accomplished. The inputs to the resolver represent δs in polar form, the outputs are δs expressed in rectangular co-ordinates. These are added to the rectangular co-ordinates of s_0 to generate s. Then the open-loop poles and zeros are subtracted from s, and each term thus generated is the input to an inverse resolver that changes the representation back from rectangular to polar co-ordinates. Then the angles of the inverse resolver outputs are properly added to obtain the net angle of $G(s)H(s)$.

In this fashion a series of values for s is found which is the root locus. Still to be found are the values of K that correspond to specific points along the locus. This can be accomplished by suitably multiplying and dividing the magnitudes of the inverse resolver outputs to obtain $|G(s)H(s)|$. For a given $|\delta s|$ input, $K = 1/|G(s)H(s)|$ satisfies the magnitude condition.

Pneumatic computers

In keeping with our earlier discussions and speculations concerning the new pneumatic bi-stable jet relay devices* under development at the Army's Diamond Ordnance Fuze Laboratory, application of these devices in computers appears to be moving closer to commercial hardware. Kearfott Division of General Precision, Inc., is developing a pneumatic digital computer utilizing pneumatic flip-flops (*5*, *6*). According to Kearfott, a unit with memory and occupying a cube less than three inches a side, will contain up to 8000 individual elements. The unit under development will operate in ambient temperatures from −100°F to 2000°F without special provisions for heating or cooling. Furthermore, it is expected to work in virtually any radiation environment, since it is devoid of all electronic and solid-state components.

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* See at 'Look at America', August 1960

Auto-controlling town's gas

Remote pneumatic equipment regulates supply to Brecon

AN INTERESTING APPLICATION OF PNEUmatic control equipment is to be found in an unmanned station controlling the flow of gas from the South Wales grid to a gas holder serving the town of Brecon. This scheme was engineered to the requirements of the Wales Gas Board by the Instrumentation Division of A.E.I., and it is understood that it has now operated satisfactorily for over a year.

Fig. 1 shows the general arrangement of the scheme, gas entering from the grid and passing *via* a jet booster to the gas holder and distribution system. Gas pressure from the grid is sensed by a pressure switch, and the gas then passes through a cylinder-operated cock and a control valve. The temperature of the gas is sensed by a pneumatic temperature transmitter, and its pressure by a pneumatic pressure transmitter. After passing through straightening vanes which ensure non-turbulent flow, the gas reaches an orifice plate.

The differential pressure at the orifice plate (up to 15 in H_2O, corresponding to a gas flow of 8000 ft³/h) is measured by a flow transmitter of the all-dry bellows type which is said to require no attention whatsoever. The output from the flow transmitter is fed to a miniature pneumatic chart recorder, into the rear of which is plugged a two-term controller operating a flow control valve. In this way the flow rate into the station can be predetermined and held at that value automatically. The recorder's chart is sufficient for one month's operation and the ink supply for six months.

The pneumatic output signal from the controller passes, *via* a valve positioner, to the flow control valve which thus maintains the desired flow of gas through the orifice plate. Both temperature and pressure readings are transmitted pneumatically to a two-pen recorder so enabling temperature and pressure conditions to be compared continuously. These recordings permit the correction of planimetered gas volumes.

The flow control valve is of the logarithmic (equal percentage) type designed for accurate regulation, and so cannot be relied upon to give complete shut-off. If the controller signals the control valve to shut fully, the signal from the valve positioner to the top of the valve is amplified by a pneumatic relay and fed to a shuttle valve. The latter then drives a spring-return valve in such a direction that the air supply closes the cylinder-operated cock.

Both shuttle valve and cock also come into action if the pressure switch on the incoming gas supply senses a fall in pressure to below a predetermined safe level, this operating a solenoid valve to feed air to the shuttle valve and close

Fig. 1 (below) Pneumatic control equipment at an unmanned station controlling gas flow to Brecon. Note flow control valve *and* shut-off cock. (PS, pressure switch; T, temperature transmitter; P, pressure transmitter; TPR, temperature-pressure recorder; F, flow transmitter; FR, flow recorder; FC, flow controller.

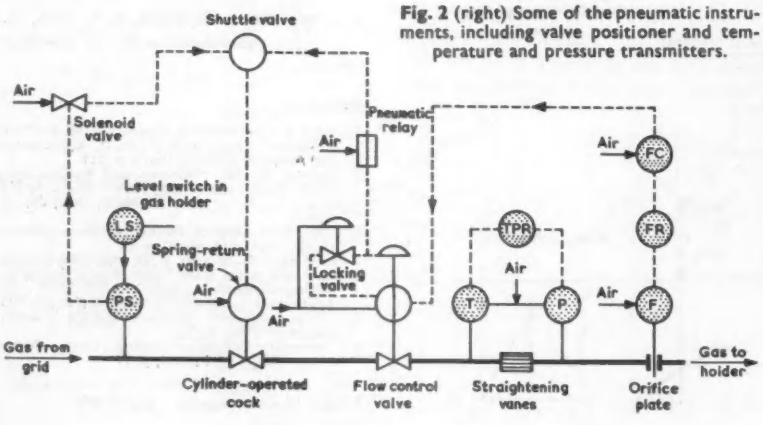
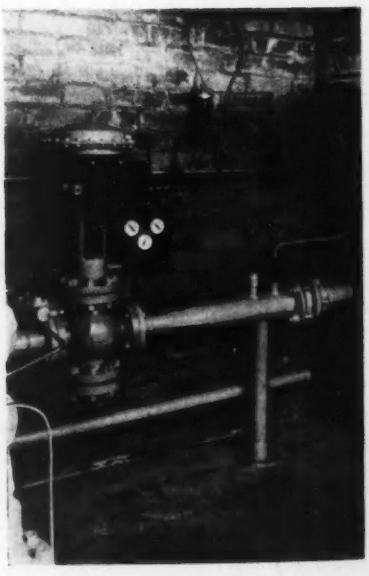


Fig. 2 (right) Some of the pneumatic instruments, including valve positioner and temperature and pressure transmitters.



the cock. A level switch mounted on the gas holder will initiate much the same operation to close the cock if maximum holder height is reached.

If the instrument air supply should fail, the flow control valve is arranged through a locking valve to 'hold' in position, and the cock will also hold fast in the event of supply failure.

It is reported that this pneumatic equipment has operated continuously since January 1960 with virtually no maintenance, and has consistently provided good chart records. The accuracy of measurement is claimed to compare very favourably with that obtained with the positive displacement meter previously used.

Capacitance-probe-controlled hopper

Hopper choking overcome by vibrator motor

A PARTICULAR MATERIALS HANDLING problem experienced in a fertilizer factory in the north of England is concerned with the flow of filter cake from a hopper. Filter cake flows from the hopper on to a feeder conveyor incorporating a Fielden Electronics' Tektor Minor capacitance probe, the latter signalling whether or not the material is flowing. Frequently the filter cake, which varies greatly in moisture content, will stick to the sides of the hopper and can build up to choke and finally halt the flow of material. Originally, when the capacitance probe signalled that the material had ceased to flow, the only solution was for an attendant to climb up to the hopper platform and strike the sides of the hopper with a hammer until the material stuck within it had been dislodged.

This not only interfered with production but also led to the walls of the hopper being so damaged as to necessitate their replacement on occasion, and this meant a further hold-up while emptying the hopper, burning out the damaged panel and welding in a new one.

After some experiment the problem was overcome by attaching an English Electric vibrator motor to the outside wall of the hopper. (This type of motor generates vibration by means of out-of-balance weights at either end of its shaft, the weights being adjustable in angle to give the required output.) A ¼hp 3000 rev/min vibrator motor was bolted to a ¼in steel plate, about twice as long as the motor, and the complete assembly then bolted at its extreme ends to the side of the hopper. The resultant 'flapping' effect of the centre of the plate against the hopper was found sufficient to maintain the flow of the material, if the motor was operated for a few seconds in every few minutes.

The Fielden electrode, within the material on the conveyor belt, will sense any change in capacitance due to the absence of material if the hopper is choked, and operate a relay to switch on the English Electric vibrator motor fitted to the side of the hopper

Now, three methods of operation are available: the operator can switch on the vibrator motor on receipt of a demand signal from the capacitance probe; a Venner time-switch arrangement switches on the vibrator motor for 10s every 10 min; the capacitance probe operates a relay to switch on the vibrator in the event of any interruption to the flow of material which could occur at times in between the automatically-timed vibrations. These three methods of control are connected in parallel and, as such, are supplementary to each other.

Control by capacitance-probe is rather more interesting than the other methods as it forms part of a closed loop: if the flow to the conveyor fails, the probe senses the resulting change in capacitance, and produces a signal which, *via* a relay, switches on the vibrator motor so dislodging material choking the hopper; the material flows freely from the hopper on to the conveyor belt where its presence is capacitance-detected by the probe which then opens the relay to switch off the vibrator motor.

The present installation is understood to maintain a continuous flow of material without attention.

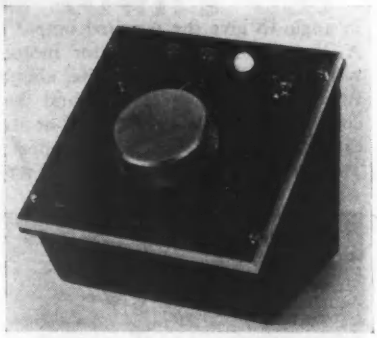
Road grader pendulum-controlled

Sperry auto-control system on Aveling-Barford motor-grader

ONE OF THE PROBLEMS ASSOCIATED with operating road graders is the difficulty of controlling the angle of cut accurately and constantly under varying surface conditions. Normally the operator has to control the machine's course and both depth and angle of cut, which is tiring and tends to lead to inaccuracy. After a study of this problem by Sperry Gyroscope, in conjunction with the contractor's-plant manufacturers, Aveling-Barford, it was decided that an automatic system for controlling the angle of cut would be well worthwhile, and allow the operator to concentrate on his course and the depth of cut. The system as designed is comparatively

Fig. 1 Aveling-Barford motor grader fitted with automatic blade control

Fig. 2 (below) The grader operator selects the required angle of cut with this control box



simple, its main units being a pendulum unit, a control box, an amplifier, a control valve, and a mercury level-switch. The heart of the system is the pendulum unit (containing a compound pendulum with an equivalent length of 40 ft) mounted on the gooseneck frame which carries the blade.

Controlling cutting-angle

The blade is set to the horizontal using an accurate spirit level initially, and the mercury switch on the back of the blade is adjusted to provide a permanent horizontal datum. To set up the machine for operation, the selector switch on the control box (Fig. 2) is put to the 'set' position (with the control dial at zero), and a set-zero control adjusted until two indicator lights (left- and right-slope, respectively) are both extinguished. The blade is then horizontal. If the angle of attack (i.e. the horizontal angle at which the blade is inclined with respect to the direction of travel) is altered, the blade must be set to the horizontal before demanding the new angle of cut. The control dial is then set to the required cutting-angle, and a signal corresponding to this is fed to the pendulum.

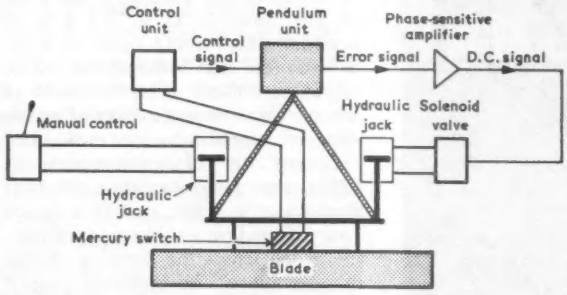


Fig. 3 (left) The system employs a compound pendulum as a constant vertical reference. The control signal is derived *via* synchros from movements of the pendulum's case, the latter being attached to the frame of the machine

The basic vertical reference for the system (Fig. 3), the pendulum, consists of a heavy cylindrical mass pivoted horizontally about its longitudinal axis, and virtually floating in oil in its case. It incorporates a synchro which gives zero output when the pendulum's case is vertical (i.e. the grader's gooseneck frame is horizontal), and the control is demanding horizontal (zero) angle. In other words, when both sets of synchro windings are in normal alignment. When the pendulum receives a command signal from the control box, an error-signal, proportional to the angular setting required, is transmitted from the pendulum synchro to the phase-sensitive solid-state amplifier. The amplified signal is converted to d.c. which varies in polarity and magnitude according to the phase of the error-signal. This operates the solenoid valve so that a hydraulic jack moves the frame on which the blade is mounted in such direction as will reduce the error to zero. The blade is then at the required cutting angle.

The system controls the angle of the blade with respect to the horizontal only, depth of cut being controlled manually by the operator *via* a separate hydraulic jack. If depth of cut is changed, or if surface irregularities tilt the grader, the pendulum case will deviate from the preset angle. The resulting error-signal will cause the auto-controlled hydraulic jack to change the blade angle until the error signal is again zero, hence maintaining constant angle of cut.

Performance

The control dial is calibrated in units corresponding to the tangent of the angle of cut, and allows settings from 6° right-hand inclination to 6° left-hand inclination. The definition is claimed to be six minutes of arc, and the speed of response such that if the depth of cut is changed at reasonable speed, the cutting angle is maintained whilst the blade is in motion.

R.A.E.'s hydraulic power vibrator

Servo-valves control vibration of heavy loads

THE VIBRATION AND FATIGUE TESTING of missiles and aircraft structures is usually carried out with equipment comprising an a.c. oscillator feeding into a power amplifier, the latter driving an electromagnetic vibration generator to which the test specimen is attached.

A new vibration generator by Dowty Rotol Ltd of Cheltenham, which has just been delivered to R.A.E., Farnborough, operates on electrohydraulic rather than electromagnetic principles. Based on the use of the well-known Moog electro-hydraulic servo-valve developed by the American firm Moog Servocontrols Inc. and manufactured in this country by Dowty, the hydraulic power vibrator applies a much higher load level over the medium frequency range than has hitherto been possible.

The Moog valve

The servo-valve itself consists of a polarized electrical force motor and two stages of hydraulic amplification.

Its motor-armature or flapper passes through a tubular flexure-pivot which acts also as a seal between the electromagnetic and hydraulic sections of the valve. At the end opposite to the motor, the flapper passes between two nozzles, creating two variable orifices between the nozzle tips and the flapper. Pressure oil is supplied to these orifices through two fixed upstream orifices, and the intermediate chamber pressures are vented to either end of the output-stage spool. The spool is of conventional four-way design and is spring-centred. Output flow from the valve, at a fixed valve pressure drop, is proportional to spool displacement.

As a signal is applied to the motor, the flapper is caused to pivot and to move between the nozzles, so that one orifice opens as the other closes, resulting in a differential pressure between the nozzle chambers. The pressure difference, acting upon the nozzle projected areas, results in a feedback force upon the flapper to balance the motor force. The pressure differential also acts upon the second-stage spool, resulting in a displacement and, hence, output flow proportional to electrical signal input.

The power vibrator

R.A.E.'s hydraulic vibrator unit consists of an oscillator and a d.c. source feeding into a servo-amplifier, and thence into two Moog valves operating in parallel. The servo-valves control the hydraulic jack vibrating the specimen. The jack is strain-gauged to give a measure of vibration amplitude, and this strain-gauge signal is fed back to the servo-amplifier controlling the Moog valves, so holding the vibration amplitude constant.

Dowty's hydraulically operated power vibrator.

The d.c. source controls the pre-loading (the mean load) on the specimen, the oscillator being concerned with vibration about that load.

Performance

During acceptance tests, with the vibrator subjecting the specimen to a mean load of 25,000 lbf, the equipment cycled between 15,000 lbf and 35,000 lbf at 45 c/s. Similar tests at 25,000 lbf pre-loading consisted of cycling between 5000 lbf and 45,000 lbf at 17 c/s, and between 0 and 50,000 lbf cycling at 9c/s. It is understood that the equipment was also tested at frequencies up to 200 c/s where—still with a 25,000 lbf mean load—the vibratory loads were ±1000 lbf; at 500 c/s the figure was ±250 lbf.

The low cost of the electrohydraulic vibrator compared with its electromagnetic counterpart is quite striking; it is believed that the R.A.E.'s vibrator cost about £5000, an unusually low figure for a machine of this power.

It is understood that Dowty are continuing development of this type of equipment. They are now building a hydraulic vibration table for operation at 500 c/s, and also have an audio (1500 c/s) vibrator.

Testing ramjets for Bloodhound

Bristol Siddeley Engines' recording system

THE RAMJET DEVELOPMENT DEPARTment of Bristol Siddeley Engines have recently commissioned a multi-channel recording system, comprising twelve Honeywell electronic strip-chart recorders, three of which are 'quarter-second' versions. The parameters recorded are fuel-flow, temperature, thrust, and pressure of the ramjet engines for the Bristol Bloodhound surface-to-air missile. A complete test run lasts for about ten minutes and recording proceeds for two minutes or so. The recorders themselves are to be fitted with digitizing units eventually.

The first recorder shows primary fuel-flow in the three alternative ranges: 20–200 lbf/h, 150–1500 lbf/h and 1200–12,000 lbf/h. The next instrument records secondary fuel-flow in the alternative ranges: 60–600 lbf/h, 600–6000 lbf/h and 3000–30,000 lbf/h. A third instrument gives tertiary fuel-flow. In each system the metering is done by Rotameter flowmeters with remote-controlled valves interconnected with the flow-range switches.

Blow-in temperature over the 0–500°C range is detected by a Hoskins chromel/alumel thermocouple, and automatic cold-junction compensation is provided within a Honeywell instrument. The blow-in temperature is normally around 200–250°C.

Thrust and drag are recorded on two d.c. energized instruments. The measuring unit is common to both systems and consists of a steel ring with two independent strain-gauge bridges. There are three ranges. Pressure is recorded on the remaining six instruments using ten balancing circuits which may be connected variously to recorders by jumper leads.

Constant-voltage stabilized units have been installed to energize the fuel-flow transmitters, and for the thrust and pressure channels. Also incorporated is a fuel-flow timer for calibrating the fuel flowmeters by measuring the time for a predetermined number of gallons to pass the existing Avery-Hardoll precision bulkmeters.

Both fuel-flow and thrust recorders have several ranges, and a range identification unit is included to emit different combinations of square-wave pulses to the marker pens of each recorder.

Main control room at Bristol Siddeley Engines' high-altitude ramjet test plant.

NEWS ROUND-UP

from the world of control

SPACE

Russia's manned rocket

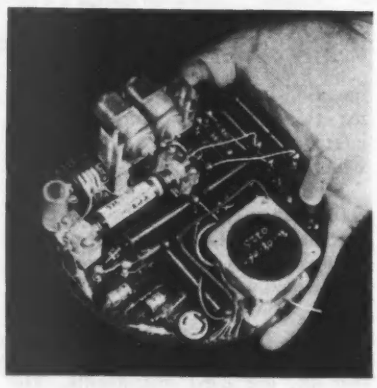
At 9.07 a.m. (Moscow time) on 12 April a multi-stage rocket carrying the satellite *Vostok*, with, as passenger, Flight Major Yury Alexeyevich Gagarin of the Soviet Air Force, was launched. After separation of the last stage of the carrier-rocket, *Vostok* went into free flight on a round-the-Earth orbit whose perigree was 181 km and apogee 327 km. The orbit took 89·1 min. The automatic orientation system was switched on at 9.51 a.m, and, after the vessel emerged from the earth's shadow, this system determined its orientation in relation to the sun. At 10.15 a.m. the automatic programming device initiated preparations for switching on the retro engine, and at 10.25 a.m. retro-rockets were fired and the machine landed safely at 10.55 a.m. According to one report Gagarin parachuted down close by, but he is reported to have said that ' the pilot was in the cabin '. The complete flight appears to have been under program control, although Gagarin is said to have been able to take over control in an emergency.

A magnificent technological achievement which enabled a brave man to become the world's first 'Pilot-Cosmonaut'. It seems a pity that an event of this importance to the world should be marred by the evasiveness of such scant information as has so far been released.

British Space Development Co.

More details of the recently formed British Space Development Co. Ltd (these columns, February) have been released. It now comprises nine founder-members, A.E.I., Associated Television, British Insulated Callender's Cables, Decca Radar, Hawker Siddeley Aviation, Plessey, Pye, Rank, and Rolls-Royce. The Chairman is Sir Robert Renwick (A.E.I., A.T.V., etc.) and other members of the Board are J. R. Brinkley (Pye), E. Fennessy (Decca Radar), G. C. I. Gardiner (de Havilland), A. A. Rubra (Rolls-Royce) and Dudley Saward (Rank). The Board intend ' to examine ways and means by which this country shall assume a significant role in space technology '.

A technical committee, under the Chairmanship of G. K. C. Pardoe (de Havilland) has also been set up. This comprises D. E. Burchett (A.E.I.), A. V. Cleaver (Rolls-Royce), J. M. C. Dukes (Plessey), W. F. Hilton (Hawker Siddeley), W. M. Lloyd (Rank), L. F. Mathews (A.T.V.), K. Milne (Decca Radar), T. P. Blott (Pye) and G. A. Dodd (B.I.C.C.). This committee is to prepare plans for British space work ' with the minimum of delay '.



SCOUT'S PACK. E. T. H. generator designed by Bristol Aircraft for the Space Research Group at University College, London. Intended for the Anglo-U.S. satellite, U.K. Scout 1, it will supply proportional gas-counter tubes detecting X-rays. The generator supplies 1600 V stabilized by a corona stabilizer to within 1·5 V, against a supply change of ±15% about 6·5 V. The output from an 8 kc/s transistor oscillator is stepped up by a transformer and voltage quadrupler, rectified and smoothed, the ripple amplitude being less than 0·005%. The current through the stabilizer tube is telemetered to provide a measure of the output voltage.

Tripartite communications

The Post Office is to co-operate with the U.S. National Aeronautics and Space Administration, and the French Centre for Telecommunications Studies, in a program for testing transatlantic communications *via* satellites. Ground stations are to be built in England and France for the reception and transmission of telephone, telegraph and television signals across the Atlantic using satellites to be launched by N.A.S.A. during 1962 and 1963 in Projects Relay and Rebound. Relay, N.A.S.A.'s low-altitude active-repeater satellite program, to be launched in 1962, will weigh less than 100 pounds. Project Rebound involves placing several rigidized inflated spheres in orbit from a single vehicle, the first launch, which should orbit three spheres, being planned for 1963.

BUSINESS

Budgeting for automation?

This year's budget contained little of interest to the control engineer in his professional capacity—and even less in his private capacity, for few practising engineers are likely to benefit from the changes in the level at which surtax is levied. However, the Chancellor's request for powers to levy a pay-roll tax if and when he feels this to be necessary, raises a number of points. This tax would require employers to pay the Exchequer up to 4s per employee per week.

It appears that the poll tax on the number of a firm's employees is expected to act both as an economic regulator in boom times, and also as an incentive to management to economize in the use of manpower when labour is scarce. Furthermore, such a tax should deter the user of automatic equipment less than the heavier, and often less-efficient, user of mass labour.

That British industry should be encouraged to install automatic controls and other labour-saving machinery is obviously all to the good. However, as a pay-roll tax would be expected to bring in around £200m in a full year, one wonders whether the intention is really to discourage the neglect of automation, or whether the Chancellor has merely stumbled upon a good source of revenue. In any event, most of the cost would probably be borne by the consumer, and there would be negligible inducement to firms still unconvinced of the value of automation.

Ultra's U.S. tie-up

Ultra Electric (Holdings) Ltd and their subsidiary Ultra Electronics Ltd, have entered into complicated arrangements with certain American organizations concerned with investment, banking and consultancy in the electronics industry.

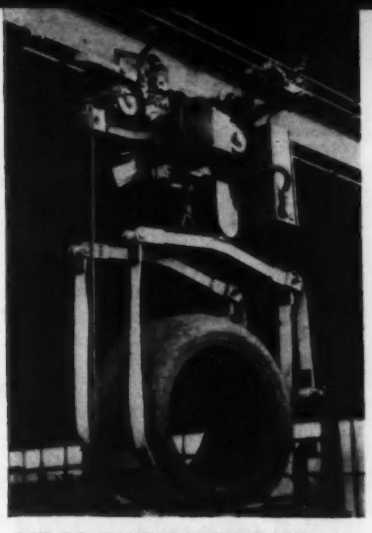
First, Ultra Electronics have agreed with Electronics Investment Management Corp., U.S.A., to exchange information on research, development, marketing, production and so forth in the field of electronics. The American firm provides advisory and consultancy services to the electronics industry in the broadest sense, operating with such company's as Potter Instrument, General Electrodynamics Corp., and Vega Electronics.

Secondly, Ultra Electric (Holdings) Ltd have sold 40% of their wholly-owned subsidiary, Ultra Electronics, to Electronics International Capital Ltd, a company registered in Bermuda. The price was £800,000 and the Bermudan concern has, in addition, agreed to make available five-year loan facilities at 8% per annum up to a maximum of £950,000, £200,000 of which has already been lent to Ultra Electronics. The balance is available if Ultra Electric (Holdings) makes similar loans to Ultra Electronics in proportion to its shareholding in that company. In other words, the Bermudan concern will lend up to £950,000, if Ultra Electric lend up to £1,125,000, so that Ultra Electronics may borrow up to £2,075,000.

There is, of course, a connexion between these two events. The management of Electronics International Capital—now 40% holders in Ultra Electronics—are also principals of Electronics Investment Trust, a $43m unit trust, and of Electronics Capital Corp., a $16.5m investment company with a substantial investment in sixteen American electronics firms. Electronics Capital Corp. are advised in their dealings with the U.S. electronics industry by Electronics Investment Management Corp., with whom Ultra Electronics are associated.

N. of W. and Vactric

The somewhat surprising news that Vactric (Control Equipment) Ltd and Vactric (Precision Tools) Ltd have been purchased by the News of the World Organization Ltd, has quite a simple explanation. It will be recalled that Vactric Ltd went into liquidation and is in the hands of the Official Receiver. The *News of the World* is diversifying its interests, and having used the products of the two Vactric subsidiaries in the newspaper business, has great faith in their products. It could be that the *News of the World* has great faith in the control and instrument industry. Sir William Carr, Chairman of the *News of the World*, will be Chairman of both concerns but the other members of their managements are unchanged, T. W. Roberts remaining as Managing Director and G. Reed, P. J. Lawson and G. E. Edwards continuing as executive directors.



OFF TO DNIEPROPETROVSK. Geo. W. King are providing the various mechanical handling and conveying systems for the Russian tire factory which is being built at Dniepropetrovsk in the Ukraine. Here a semi-automatic overhead conveyor system—note adjustable sling—undergoes test. Some £14m-worth of engineering service plant and rubber and tire manufacturing machinery is being supplied from Britain for this fully mechanized and highly automated plant which will produce 2,000,000 tires a year of all types. Dunlop Advisory Service are consultants to the British consortium known as Rustyfa, which is supplying the plant, members of the consortium being Mather & Platt, Simon Handling Engineers, Crompton Parkinson, David Bridge & Co., Francis Shaw & Co., and Lancashire Dynamo.

Bruce Peebles–Rega agreement

The operation and control of both ferrous and non-ferrous hot and cold rolling mills is the subject of an agreement between Bruce Peebles of Edinburgh and Rega Brucker & Co., Seigburg, Germany. The agreement covers the joint production and marketing in the U.K. and Eire of complete electrical equipment for this duty. Rotating machines and rectifiers will be built by Bruce Peebles, and the electronic controls, programming, optimization, and automatic gauge-control equipment designed by Rega Brucker and manufactured either by them or, under licence, by Bruce Peebles.

AVIATION

A.T.C. symposium

The symposium on air traffic control held by the Royal Aeronautical Society on 20 April, left *Control* full of admiration for the practising air traffic controller but with some fear for the future. It appears that the accelerating rate at which more and faster aircraft are coming into service is placing a great strain on the a.t.c. service, and that, in this country at least, the adequacy of the service is due to the work of the individual controller rather than to technical achievement.

At present a.t.c. is more of an art than a science and, although there are plans for easing the situation by the use of data processing equipment, improved radar coverage, etc., these plans appear to be some years from fruition. Arnold Field, Master of the Guild of Air Traffic Control Officers said that a controller must be able to think in 'space and time' and recognize a three-dimensional situation from a two-dimensional display, while excluding irrelevancies; he is a human computer accepting oral information from aircraft and his fellow controllers, and possibly listening to bells and buzzers also, and visual data from radars, television, charts, instruments, and lights—some of them coloured. He must receive and store this information, along with other data such as a particular aircraft's speed, manoeuverability and performance, recognize priorities and take action.

Controllers under stress

This may lead to stress fatigue: a controller's performance will deteriorate, he will concentrate on a single aspect, rather than the whole of a situation, and may fall into inexplicable error; he will show anxiety in a complex situation and doubt his ability to handle it; after long exposure to stress he may, on seeing a complex situation arising, feel unable to continue. J. L. Anast, of the American Federal Aviation Agency, pointed out that more errors could occur when a controller was lightly loaded than when he was working at peak load.

Several suggested that there should be a proper study of the ergonomics involved. Apparently there have been some rather half-hearted attempts at studying the psychology of the controller, but these have come to little—in one case the psychologist concerned succumbed to a nervous break-down.

In this country both Ferranti and Elliott computers are going into use at present, but it is in the United States that a.d.p. is having the greatest impact, although even there the fully automatic system is many years away. Anast of the F.A.A. reported that there are I.B.M. 650s or Univacs in six centres busily printing flight strips; these computers are giving confidence in a.d.p. to the a.t.c. organization rather than themselves making any great change. He did

warn against underestimating the programming problem, saying that for a particular job between fifty and a hundred programmers were necessary, quite apart from systems analysts.

Discussing the reliability problem, Anast said that a.t.c. needs occurred in surges, so that over-design was necessary. An a.t.c. computer should be backed by a stand-by machine, and both machines should be designed so that a single type of replacement unit could take the place of several different parts. This stand-by, or even duplex, system should enable the human controller to take over in an emergency.

To sum up: the human controller is doing a good job under difficult circumstances, a job that is bound to become increasingly difficult at an accelerated rate. Much thought has been given to automating his task but progress is slow.

B.C.A.C.

Automation—men and money

A conference on the social and economic effects of automation, 'Automation—men and money', is to be held under the sponsorship of the British Conference on Automation and Computation from 27–30 June. The conference will open with a plenary session at which Lord Hailsham, the Minister for Science, will speak, and will continue with papers discussing the economic and social aspects of the subject from both the employers' and the general point of view. Case studies will be presented and, in a final plenary session, Sir Walter Puckey will review the Conference. Further details are available from Mrs J. Hodson, Conference Secretary, The British Institute of Management, 80 Fetter Lane, London E.C.4.

EDUCATION

Training in auto-control

On 7 April, the S.I.T. forgathered for an all-day meeting at the Northampton College of Advanced Technology to consider aids to training in automatic control, and training equipment from educational and other establishments was exhibited. After general inspection of the equipment in the morning, each apparatus was described by a demonstrator in the course of the afternoon. Some simple devices exhibited by the University of Southampton and Birmingham C.A.T. served as a reminder that automatic control is not an isolated science, but is closely concerned with the fundamental principles of dynamics.

Simulation exhibits ranged from commercially-available electronic boxes to R. S. Medlock's ingenious mechanical device of the string and bent-wire school, the latter being designed to show lag and attenuation of a plant under various forms of control. Taylor Controls and Northampton College both showed useful-looking model control-loops using standard pneumatic process-control equipment.

The discussion which followed the meeting brought up the question, *inter alia*, of the value of simulating mechanical behaviour on electronic equipment. Differences of opinion were apparent, but it seemed generally agreed, at least as far as 'mechanical' students were concerned, that electronic simulation on its own was of little value. J. E. Fisher and K. C. Garner advocated the method used at Cranfield, where practical work on a mechanical system is immediately followed by simulation of the same system on a computer.

RAILWAYS

B.R.'s modernization plant

As *Control* goes to press, a comprehensive account of the engineering work involved in the plan for the modernization of British Railways is being presented to the Railway Modernization Conference at the Institution of Civil Engineers (3–4 May). The Conference which is a joint venture of all three Institutions, Civils, Mechanicals and Electricals, includes five papers by senior railway men, and a great deal of interest to control engineers is being discussed.

R. C. Bond, who is the B.T.C.'s Technical Adviser, is presenting an introductory paper, *The engineering aspects of the modernization plan for British Railways*. He points out that higher speeds and more intensive services entail new signalling arrangements, and refers to such matters as: automatic warning systems of train control; modifications to signalling equipment as a direct consequence of high-voltage a.c. electrification; signalling in hump marshalling yards and the provision of electronic control equipment for electro-pneumatic retarders; and telecommunications.

The contribution of civil engineering to the B.R. modernization plan by M. G. R. Smith, Chief Civil Engineer, Western Region, also refers to control systems—in spite of his title. He mentions the reduction in marshalling yards and points out that: 'They have electronically controlled equipment which. according to the destination, weight, rollability of wagon, the space available in the siding to receive it, and the weather conditions, automatically guide and control the speed of each wagon, or cut of wagons, from the hump to join other wagons for similar destinations in as many as 48 different sorting sidings'.

Supervisory remote control

The B.T.C.'s Chief Electrical Engineer, S. B. Warder, is presenting *Electric traction in the B.R. modernization plan*, a paper of some control-engineering interest. He discusses track feeder protection, for example. This entails measuring the impedance of the current path by balancing the current against the voltage at the relaying point, and tripping the circuit breaker when the ratio of voltage to current is below the normal for the protected section. In supervisory remote control, a coded voice-frequency system over four wires is used, and each controlled station is allocated a frequency in the 400 c/s–4000 c/s band. Selection is by turning a mimic diagram discrepancy key, so transmitting a train of impulses which select the equipment to be controlled.

B.R. modernization—signal engineering and telecommunications by J. F. H. Tyler, Chief Signal and Telecommunications Engineer, Southern Region, is of direct interest to the control engineer. Tyler discusses signalling and telecommunications in some detail, refers to automatic marshalling yards with radar wagon-speed detection and electropneumatic points and wagon retarders, and mentions the new automatic lifting barriers used in lieu of level-crossing gates.

Automatic train control

He also discusses A.W.S., the automatic warning system being installed on all important lines. This is a development of the Hudd system in which brake application is initiated as the engine receiver passes over a permanent magnet, but is cancelled if the engine receiver passes within a predetermined time over an electromagnet energized to give polarity opposite to that of the permanent magnet.

If a distant signal is at 'caution', or a multiple-aspect colour light signal is at 'caution' or 'danger', the electromagnet is de-energized and the brakes are applied automatically. If the signal is at 'clear', the electromagnet is energized and the initiation of brake application cancelled.

ELECTRICITY

C.E.G.B. opens up

Two new C.E.G.B. power stations were officially opened during April:—Elland, near Wakefield, and Spondon 'H', near Derby. Spondon 'H' is unusual in that one of its primary

UNIFIED The C.E.G.B.'s Elland power station has a combined control panel for each boiler-turbo-alternator unit.

CLASSICAL At Spondon boiler control panels face the firing aisle of the chain-grate-stoked boilers.

functions is to supply steam to a neighbouring British Celanese factory, and it is the first C.E.G.B. station specifically designed for this purpose. The four Foster Wheeler boilers are relatively small by current C.E.G.B. standards, having a maximum evaporation rate of 180,000 lb/h each. Automatic control of steam temperature and furnace pressure is provided by James Gordon equipment, the combustion and steam pressure being manually controlled. Steam temperature control is obtained by the regulation of the water flow to a condenser between the steam drum and the superheater. To overcome the slow response of the temperature-sensing system to load changes, an overriding control working from an air-flow signal operates the water-flow regulator when rapid changes of load occur. The steam, which leaves the boilers at 950 lbf/in² and 895°F, is supplied *via* four A.E.I. back-pressure turbo-alternators each rated at 10,120 kW.

Elland is a more conventional station designed on the 'unit' principle, each boiler and its associated turbo-alternator being controlled from a combined panel. The boilers, comprising one Yarrow and two John Brown Land, and each rated at 550,000 lb/h, are all fired by pulverized locally-produced fuel of low quality. Automatic control of steam pressure, superheat temperature, and combustion conditions is provided by George Kent equipment. The temperature control on the Yarrow boiler follows the now-common C.E.G.B. practice of varying the burner-tilt, with limitation of the tilt-angle by spray desuperheating. A similar limitation is employed on the John Brown boilers, where the basic control is by gas bypass. The boilers supply steam at 950 lbf/in² and 900°F to three Metropolitan-Vickers turbo-alternators, each having a maximum output of 60,000 kW.

NEWS BRIEFS

The future of the seven, a one-day course on the European Free Trade Area is being held in London on 18 May. Details: The Course Secretary, Federal Trust, 10 Wyndham place, London W.1. Telephone: Paddington 6670.

Northern computing service has been set up in Manchester by Ferranti. Initially the service will be based on a Pegasus digital computer at Ferranti, Hollinwood.

Plessey have purchased the freehold of their plants at New Lane, Havant, Hants., and at Wood Burcote Way, Towcester, Northants., for over £0·5m. Both plants are operated by the Components Group.

Kompass Register, an industrial and commercial reference work, is to be published by Kompass Register Ltd, Therese House, 29-30 Glasshouse Yard, Aldersgate Street, London E.C.1.

Electronic cheque sorter capable of sorting cheques and other documents at up to 750/min has been delivered to the Westminster Bank's Lombard Street premises by National Cash Register. The machine employs a magnetic-ink character system.

Martonair's *Journal of applied pneumatics* is to run courses on applied pneumatics. Details: The Director, Journal of Applied Pneumatics, Parkshot, Richmond, Surrey.

Atlas, Ferranti's advanced digital machine which has an addition rate of about 1,000,000/sec, is to have two Plessey memory systems with access times of 0·35 and 0·6 microseconds, respectively.

Seacat: Sperry have been awarded an Admiralty contract for major items of seaborne equipment associated with the control of the close-range surface-to-air missile Seacat.

Plessey have concluded a licence agreement whereby they will manufacture the thermal overload protectors and starting relays of Elettrotecnica Rini S.p.A., Milan.

Measuring, testing and control instruments of the Bach-Simpson Co., Canada (an associate of Simpson Electric Co., Chicago) will be marketed by Aveley Electric.

STEEL

Changes at Bisra

Although the British Iron and Steel Research Association is well known for its interest in control engineering, recent changes within the Association appear to point to an even greater concern with the subject. First, the ertswhile electrical engineering section has been renamed the control engineering section, and placed under a new chief, J. P. Clyne, who was with Sperry Gyroscope. Secondly, Dr L. N. Bramley, who headed the section for many years, has been given a roving commission concerned with automation and information handling. *Control* understands that he will act as a consultant concerned with the problems of both the steel industry itself and with suppliers of equipment to that industry.

Furthermore, M. H. Butterfield's Automation Section within the Physics Department has been renamed the Systems Engineering Section. The work of this section overlaps to a very large extent with that of the Control Engineering Section, and the change in title appears to be connected with an attempt to define the duties of the two sections. It will be appreciated that the Physics Department was at one time the source of many things electronic and, therefore, its stake in the control business is self-evident.

PEOPLE IN CONTROL

by Staffman

SIMPSON SHOOP HUGHES PURCHES
golden bonds

'Systems engineering treats a manufacturing process as a unified whole, subject to a single control mechanism which on the scale of modern industry may justify the use of more sophisticated methods than have been considered necessary in the past.' So said **W. K. Hutchison** in his Presidential Address, *Industry, science and the chemical engineer,* at the Institution of Chemical Engineers' A.G.M. on 25 April. He continued, 'The chemical engineer of the future will have to understand the underlying principles of control and must be able to use all the tools that modern computer techniques have placed at his disposal for process control and for the optimization of design'.

Both Plessey and Solartron have appointed Chief Inspectors recently, these men having an aviation background. Plessey's new Company Chief Inspector, **L. Walker**, was previously with Scottish Aviation and B.E.A. and, before the war, Imperial Airways. Solartron's man, **Edwin Dunne**, was Deputy Chief Inspector at de Havilland Propellers, Cossor's Chief Inspector, and with the A.I.D. I suppose the aircraft world's proper preoccupation with inspection means that they lead in the art.

DUNNE WALKER
tickets please!

R. F. G. Hamilton, who has been appointed Manager of Elliott Brothers' Servo Components Division in succession to **D. Ince**, became Technical Manager of the Division early last year. Prior to joining Elliott's he was with Waygood-Otis and Plessey. I believe that Ince is taking up new duties within the Elliott-Automation Group, duties connected with the export of aviation equipment.

The new Sperry associate, Wright Machinery Co. Ltd, which took over the check-weighing business of Industrial Products (Speco) Ltd, has **W. J. Ellison** as General Manager. I gather that his first task will be connected with the U.K. manufacture of products developed by the American Wright Machinery Co.—a division of Sperry Rand Corp. Ellison is well known in packaging circles having been with Packaging Machinery (Peters) Ltd and Beans Industries Ltd.

ELLISON
package deal

OWEN
branching out

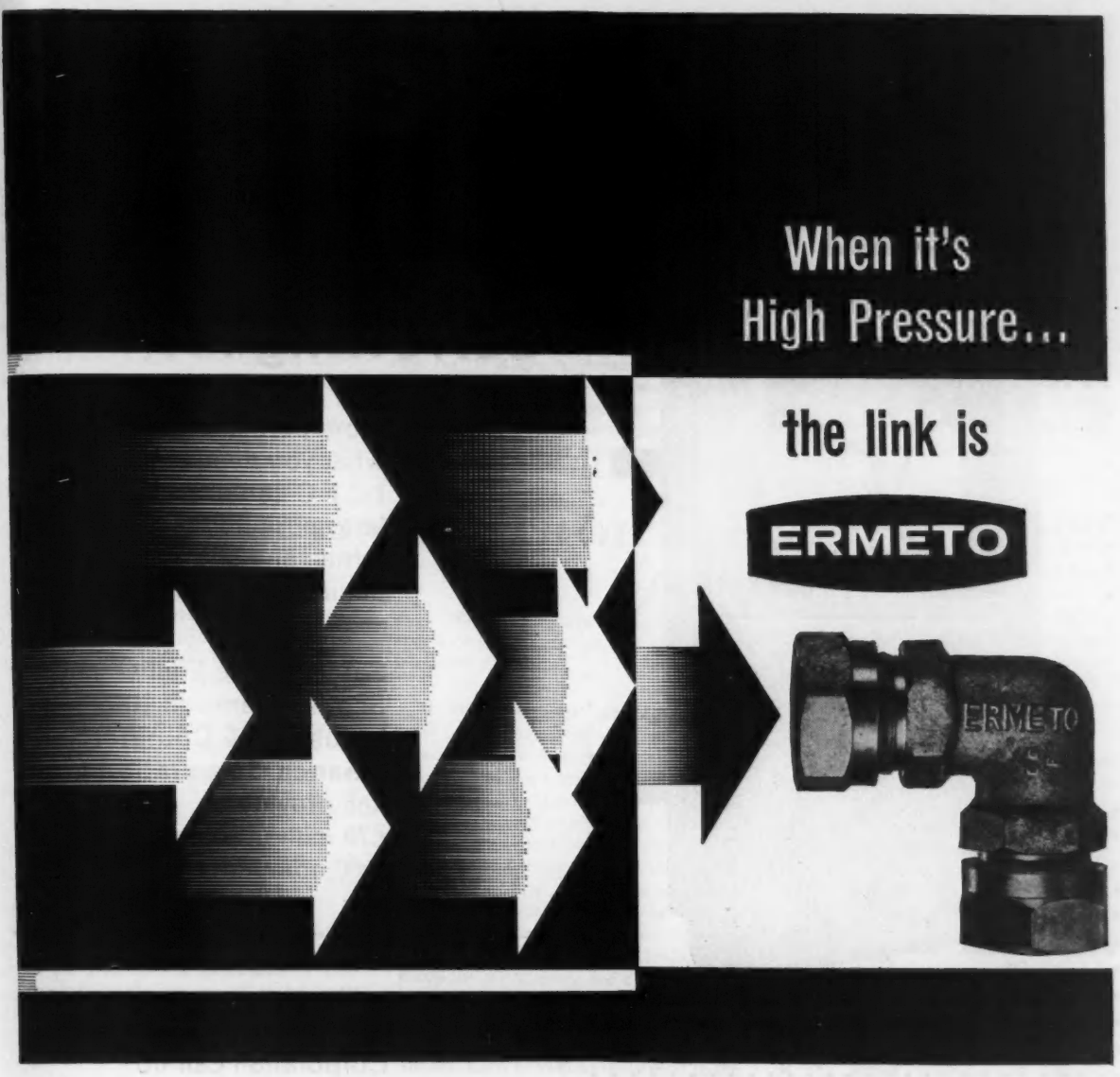
The complete instrumentation of the Steel Company of Wales' Trostre Works, from inception to commissioning was, I am told, the responsibility of **W. R. Owen,** recently promoted by Honeywell Controls. Owen is now in charge of Honeywell's Cardiff and Manchester branches in addition to continuing as Birmingham Branch Manager. Apart from his S.C. of W. experience and, of course, nine years with Honeywell, Owen spent two years with Elliott Brothers. Other recent Honeywell appointments include that of **T. Jackman** as Field Sales Manager for heating, ventilating and air-conditioning controls, and **R. Robson, E. R. Amery** and **H. Wigman** as Market Sales Managers for the metal processing, chemical, and food and fibre industries, respectively.

The happy group surrounding the serious lass in my heading illustration are, left-to-right, **David Simpson,** General Manager of Hughes International (U.K.) Ltd, General **C. A. Shoop,** Vice-President of Hughes International U.S.A. (and Managing Director of the Scottish company), and Lord **Hughes** and Brigadier **A. R. Purches,** Chairman and General Manager, respectively, of the Glenrothes Development Corp. The lady is inspecting gold-bonded germanium diodes after their assembly on a fully-automatic sealing machine.

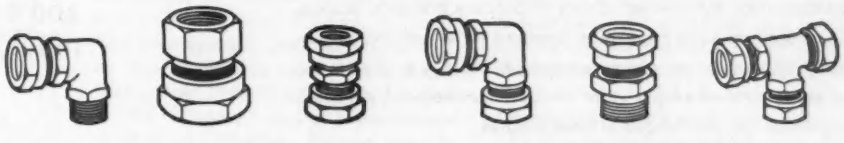
It could be that control engineering within the Albright & Wilson group of companies will receive a fillip from the appointment of Dr **R. A. Gregory** as head of Inter-Company Planning. That Gregory is well aware of the value of process control to the chemical industry —and also of certain shortcomings of the instrument industry—is obvious from his Viewpoint, *Chemistry and control,* which appeared in *Control* last December.

You may recall Ultra Electronics' acquisition of a one-third share in Miles Electronics. Now **Geoffrey Barnes,** a new executive engineer with Ultra Electronics, has been appointed their liaison officer with Miles. Incidentally, I gather that Ultra Electric have sold 40% of their holding in Ultra Electronics to Electronics International Capital Ltd 'a company created by a Special Act of Parliament in Bermuda', so I suppose we may yet hear of a Bermudan liaison officer in Western Avenue.

Last month I reported **J. Bell**'s appointment as Managing Director of M-O Valve, vice **G. A. Marriott** who has retired. However, the matter does not rest there, for Marriott was also President and Chairman of Vasca—the Elec-



Ermeto high pressure pipe fittings work on a completely different principle from any other type of fitting. The Ermeto joint incorporates a metallic "lock" which ensures a secure pressure tight joint under severe operating conditions. Ermeto couplings are made in mild steel, stainless steel, brass, aluminium alloy and high duty bronze. Couplings, valves, hose fittings and assemblies are available in a wide range of types and sizes. Non-standard fittings can also be produced to specific requirements. A copy of the Ermeto catalogue illustrating the comprehensive standard range will gladly be sent on request. Technical advice is always readily available.



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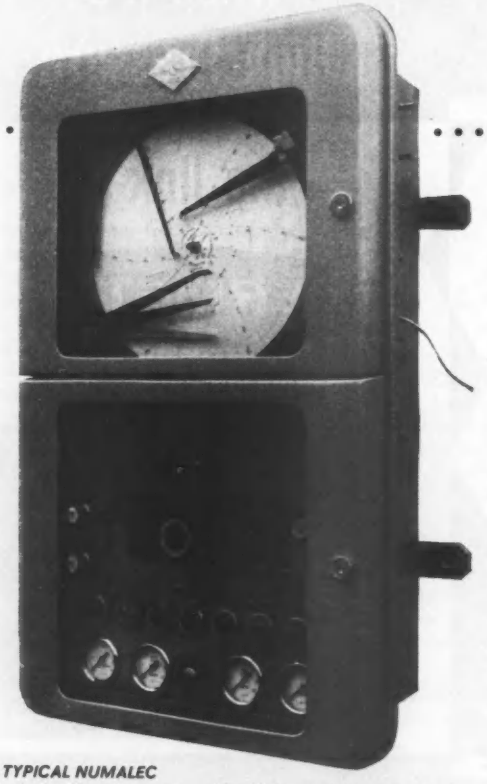
More processes under CONTROL with the Cambridge Numalec



A TYPICAL NUMALEC
Cambridge Numalecs vary considerably in appearance, since each is made to customer specification. Standardised components greatly reduce costs, however.

The first Numalec Controllers were made for the food industry and helped to make the canning of peas a dependable process, almost free from the risks of human error. Now, Numalecs are being made for a wide variety of control-plus-co-ordination applications — from the dyeing of textiles to the control of humidity during the drying of roof tiles.

One of the latest process control projects for which a Numalec has been designed is for the sterilisation of surgical gloves, dressings and fluids.

The Cambridge Numalec will control temperature, pressure, vacuum, and co-ordinate some mechanical functions for set periods (adjustable at will) and in the sequence required. There is no limit to the number of different stages which can be accommodated. An entire programme can be changed in three minutes.

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tronic Valve and Semi-Conductor Manufacturers' Association—and his retirement entailed changes within that Association. **S. S. Eriks**, Managing Director of Mullard, becomes President and Chairman of Vasca's Council, and **C. A. W. Harmer**, a director of Pye, Chairman of the Association.

Wayne Kerr, the transformer ratio-arm bridge and transfer-function computer people, seem to be very busy of late. Now I learn that their Technical Director, **Geoffrey Gouriet**, and General Sales Manager, **Gordon Ball**, are in the U.S.A. They are showing the t.f.c. at the I.R.E. Show, and intend lecturing on the instrument's merits to a wide variety of

BONES

HINKLEY

down to earth

would-be users. Wayne Kerr recently took on Dr **Roger A. Bones** as Head of the Contracts Division. He was a member of de Havilland's Blue Streak team and responsible for technical assessments of trials among other things.

I see that **D. T. N. Williamson**, whose article *Computer control of machine tools* aroused so much interest when it appeared in *Control* in July and August 1958, has left Ferranti, Edinburgh, where he was Manager of the Machine Tool Control Department, to join Molins Machine Co. As Molins' Director of Research and Development, Williamson should have plenty of scope for the company's cigarette-making machinery is highly automated. His position as Manager of the Ferranti Machine Tool Control Department goes to **H. G. Hinkley**, an ex-T.R.E., Malvern, and B.E.A. man who joined Ferranti in 1948 to establish and operate their Trials and Flying Units.

AUTHORS IN CONTROL

A. J. Wakefield (*Operating a power station with a computer*, page 84) studied mathematics at Jesus College, Oxford, obtaining a first-class honours degree in 1948. He then carried out research into problems of statistical thermodynamics and obtained the degree of Doctor of Philosophy. In 1951 Dr Wakefield joined the Research Laboratories of Elliott Brothers (London) Ltd at Borehamwood, and has since worked in various of the Elliott-Automation group's divisions. From 1951–54 he was with Elliott's G. W. Division designing and programming analogue computers, Tridac in particular, and in 1955 joined the Computing Division as a system analyst. There he did programming investigations connected with the design of such digital computers as the National-Elliott 405 business machine and the 803 general-purpose computer. Dr Wakefield joined

WAKEFIELD

Panellit Ltd in 1959, and did development of the Panellit 609 in collaboration with I.S.I. (formerly Panellit Inc.) at Skokie, Illinois, U.S.A. He programmed a 609 computer now working in a steel mill.

G. B. Marson (co-author with I. C. Hutcheon—below—of *Electronics in industrial process control*, page 88). See page 111, March 1961.

I. C. Hutcheon. See page 111, March 1961.

P. F. Blackman (*Pole-zero approach to system analysis*, page 92). See page 126, November 1960.

J. W. W. Shaw (*Supply and regulation of boiler feed-water*, page 96) served an apprenticeship with the Consett Iron Co. and received his technical education at Consett Technical Institute and Rutherford College, Newcastle-upon-Tyne. After a period as maintenance engineer, he accepted an engagement to supervise the installation of Diesel-electric power stations and mechanical equipment in a number of gold mines being sunk in Northern Victoria, Australia. On his return to England he joined the Air Ministry, and during the war was engaged on the final inspection and certification of 'safety for flight' of experimental and production front-line fighter aircraft. Early in 1946 he transferred to the Department of Atomic Energy and was a member of the original team engaged on the design of Britain's first atomic reactor, B.E.P.O. Since then he has been engaged on the design of the Dounreay fast reactor and the Calder and Chapelcross thermal reactors. He is now an Assistant Chief Engineer with the Production Group, U.K.A.E.A., responsible for reactors.

J. H. Westcott (*Adaptive control*, page 99) was educated at London University, and an engineering apprentice at B.T.H., Rugby, from 1937 until he joined the Radar Research Establishment in 1942. He was a research student at Imperial College from 1946–50, during which period he was a 'guest' of the Massachusetts Institute of Technology for one year. In 1950 he became Lecturer in the Electrical Engineering Department at Imperial College; since 1957 he has been Reader in Automatic Control. Dr Westcott has been a Member of the Councils of the I.E.E. and the S.I.T. and a consultant to A.E.I., Shell, the Ministry of Aviation and Feedback Ltd. He is *Control*'s consultant on systems, and is the author of 28 publications on automatic control—for the most part on the theory of linear control systems with, recently, emphasis on the statistical analysis of signals and statistical problems in connexion with control system design.

WESTCOTT

ROACH

M. G. Hartley (*Versatile analogue computer for g.w. studies*, page 103). See page 130, April 1961.

R. F. Roach (*Closed-circuit television*, page 109) trained at S.E. London Technical College. For ten years he was with Elliott Brothers (London) Ltd, where he went through the shops learning to be an instrument maker, finishing up on the design staff dealing with remote control gear. He served in R.E.M.E. for thirteen years as a regular officer, during which time he held a number of appointments including that of Chief Instructor of the Radar and Fire Control Training Battalion R.E.M.E., Workshop Commander, and officer in charge of a development and technical publications unit concerned with servo-systems, optical instruments and electro-medical equipment. While serving in Germany he was technically responsible for the purchase, inspection and commissioning of a fully-mobile sixty-channel radio relay system. On leaving the army he became the General Manager of the Stabilag Company. Major Roach is now with the United Kingdom Atomic Energy Authority.

New for Control

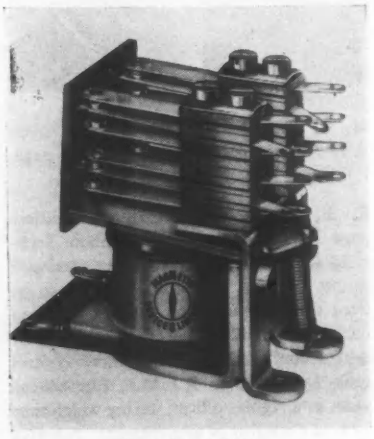
A product review for the control and instrument engineer

For further information, circle the appropriate number on the reply card facing page 162.

LIGHT DUTY RELAYS

a.c. or d.c. operation

Magnetic Devices' series 600 (a.c.) and series 605 (d.c.) relays are compact units with coil and contacts tested to 1500V r.m.s. to earth. Maximum contact arrangements are four pole normally closed, four pole changeover, or six pole normally open. Palladium contacts are fitted for low currents, or fine silver contacts to switch up to 5A, 30V d.c., or 5A, 250V a.c., with a non-inductive load. Coils are available for a.c. operation at 6, 50, or 250V a.c. (series 600), and for d.c. operation at 6, 12 and 250V (series 605). Operating and release times are 12ms and 11ms respectively. These relays may be supplied as enclosed or hermetically sealed units, mounted on plug-in or solder hook bases.



Tested to 1·5 kV

Circle **No 559** on reply card

TRANSISTOR D.C. AMPLIFIER

chopper stabilized

Honeywell's Accu Data III transistor d.c. amplifier is intended primarily for use with strain gauges and thermocouples. An output of 10V or 50mA is obtainable for signal inputs down to 0·15mV (single ended) or 10mV (differential). Frequency response is from d.c. to 20kc/s, with noise and drift quoted as less than 0·007% for typical gains. It has seven calibrated single-ended gain positions, three differential gain positions, and a ten-turn potentiometer for intermediate gain settings. The self-contained power supply requires 10W at 115V, 50–400 c/s; a 130 V model is also available.

Circle **No 548** on reply card

OSCILLOSCOPE

chemical analysis indication

An instrument by Bruce Peebles, the C-Scope, is designed for displaying information from chemical analyses. A typical application, developed with Griffin and George, is gas chromatography. Information is shown on a 14-in long-persistence cathode-ray tube, and facilities are provided for rapid expansion or contraction of the time base so as to show part of a chromatogram or a series of chromatograms. Modular construction is used, with plug-in transistorized units.

Circle **No 535** on reply card

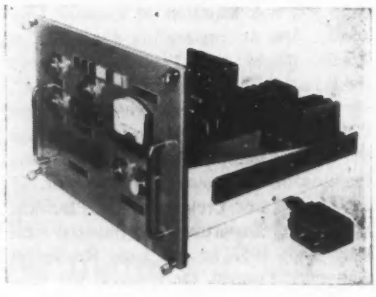
RATE CONTROLLER

digital comparator

Jordan Control's (U.S.A.) comparator provides accurate control of any function which may be made to produce a pulse-rate or frequency proportional to that function.

The principle of operation is the comparison of the frequency of the output of some form of transducer with a reference frequency derived from the comparator. If the transducer output changes to a frequency different from the reference, a beat frequency is generated in the comparator. This is used to provide a signal which will operate controllers in the system until the frequency of the transducer output returns to equality with the reference frequency.

Solid-state circuitry



Circle **No 557** on reply card

HIGH-PRESSURE VALVE

very low leakage

A solenoid valve by Hymatic is designed for use with high-pressure gas, normal working pressure being 4500 lbf/in². Developed originally for an armament application, the valve is series-tested in production down to −45°C; also, the leakage at −65°C is given as less than 0·004ft³/min. The very low leakage allows venting of the down-stream system when the valve is closed. .

The standard model has a response time between 150 and 300ms, a temperature range of −45 to +70°C, and will work unrestricted at accelerations up to 12*g*. The MD30 has a through area of ¼ in B.S.P. size, and weighs 2½ pounds; it meets design requirements AVP.970, DES.1, and EL.1384.

Working pressure 4500 lbf/in²

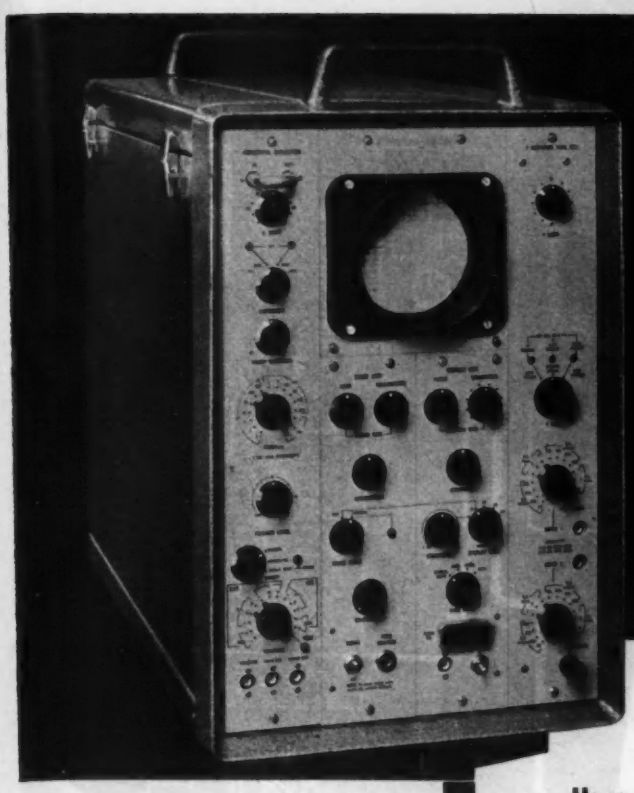
Circle **No 547** on reply card

ADJUSTABLE-SPEED DRIVE

stepless control

Lancashire Dynamo's series BMC 1 range of bridge motor-controllers is designed to provide stepless control, over a 10:1 speed range, of motors rated at from 1 to 3·5hp. The d.c. supply to the motor-armature is derived from a rectifier circuit using thyratrons and silicon rectifiers in a bridge circuit.

An electronic servo-control system continuously samples armature voltage as a measure of motor speed, and this voltage is compared with an internal reference. Any difference between them produces an error signal, which is fed



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to the grids of the thyratrons in the armature supply unit so as to increase or decrease the supply to the armature according to whether the motor is running slow or fast. It is claimed that any speed set within the 10:1 range will be held within ±1% of motor base-speed for load variations from zero to full load. If the machine is run with a constant load, speed is maintained to within ±2% for mains supply variations up to ±12%. An additional feature, incorporated to compensate for the drooping load/speed characteristic which would result from only armature control being used, is that a voltage proportional to the motor current (hence load) is injected at the control-circuit input to compensate for increased *IR* drop as the current rises.

Circle **No 564** on reply card

MINIATURE INTEGRATING GYRO

low drift-rate

Now available from Ketay is Norden's (U.S.A.) RI–203 miniature integrating gyro. Features are low drift-rate, quoted as less than 0·02 deg/h random drift, and a day-to-day stability of 0·1 deg/h without trimming. The spin-motor turns at 12,000 rev/min, which contributes to the

Long working life

motor's 3000 h life. Dimensions are 3·1 in long by 2 in diameter; weight, including shields and heater, is one pound.

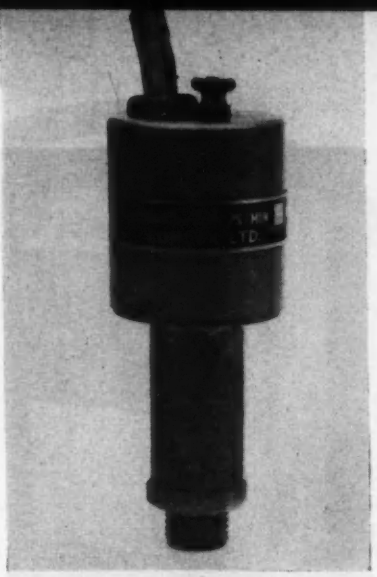
Circle **No 534** on reply card

PRESSURE SWITCHES

snap-action contacts

Miniature pressure switches, designated PS/MIN.1 to PS/MIN.3, are available from Londex. The silver contacts are rated 5A, 250V a.c. or 2A, 30V d.c., for resistive loads, and 2A, 250V a.c. or 1·5A, 30V d.c., for inductive loads.. The three types have maximum pressure ratings of 200 lbf/in², 300 lbf/in², and 350 lbf/in² respectively, with corresponding reset differentials of 1¼ to 2¼ lbf/in², 3 to 5 lbf/in², and 6–14 lbf/in².

These switches will operate in non-



Maximum temperature 100°C

corrosive fluids up to a maximum temperature of 100°C, and are pre-wired with 4ft of 3-core cable. Net weight is 5 ounces. A double-pole change-over version, the PS/MIN/DP, is also available to order.

Circle **No 549** on reply card

COMMUTATING SWITCHES

20 c/s operation

Mechanical commutating switches by Advanced Technology Laboratories (U.S.A.) may be supplied in one- or multi-pole configurations for commutating 64 or 100 channels of information at an operating speed of 20c/s.

A jet of mercury replaces the conventional wiper arm, and it is claimed that the inherently low wear allows up to a thousand hours' continuous operation, and that cleaning contacts and mercury then restores the switch to 'almost new'. The model 210 Deltaswitch is now available from stock.

Circle **No 556** on reply card

MULTI-CHANNEL RECORDER

low-inertia system

Made by Abem (Stockholm), the Ultragraph recorder is available in the U.K. from Smiths Industrial Division. A low-inertia system allows the recording of signals at frequencies up to 5000 c/s. An intense beam of ultra-violet light is deflected across six-inch sensitized paper by mirror galvanometers, so providing traces of individual inputs.

The standard model has two magnet assemblies, each accommodating seven channels. The paper-drive mechanism gives speeds from 0·1 to 0·8 cm/s, with a setting accuracy of 2%. An integral timing-device registers timing lines across the width of the paper at intervals of 0·1 and 1·0 s.

Circle **No 531** on reply card

FREQUENCY METER

covers 3 c/s–1·65 Mc/s

Made by General Radio (U.S.A.) the 1142-A pulse-counting electronic frequency-meter and discriminator is claimed to achieve a direct-reading accuracy of 0·1% by virtue of a calibrated scale-expansion technique.

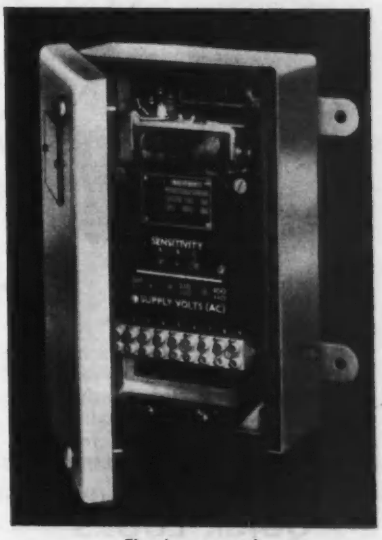
Input sensitivity is 20 mV, and discriminator residual noise is 100 dB below full scale. A d.c. output is provided for operating a recorder. Available in the U.K. from Claude Lyons.

Circle **No 530** on reply card

LIQUID-LEVEL CONTROLLER

adjustable sensitivity

A new range of Lectralevel control units and electrodes is now available from Londex. The units operate by sensing the conduction of a small current through the liquid, electrolysis being avoided by the use of low-voltage a.c. A sensitivity selector in the control unit makes it possible to adjust for a wide range of liquid conductivity. The LL/U1 has single-pole silver change-over contacts rated at 2A, 450V a.c. or 4A, 250V, a.c., and operates from 200 to 250V or 400 to 440V a.c. mains. Other models available are the LL/HS, for use with liquids of very low conductivity, and



Floatless control

the LL/U2, a robust unit housed in a weather-proof casing; this model has contacts rated 20A, 440V a.c., and a pair of auxiliary change-over contacts rated 4A, 250V a.c.

Circle **No 563** on reply card

ELECTRONIC MICROSWITCH

single-pulse output

A unit available from Honeywell Controls comprises a single-pole double-throw switch, and a pulse-circuit consisting of a capacitor, resistor, magnetic core, and diode.

Operation of the switch charges the capacitor through the normally-open circuit; this switches the square-loop core which produces an output pulse to the load. Release of the switch discharges the capacitor and resets the core, the negative voltage produced being blocked by the diode. In the normal (unoperated) condition, the

circuit is isolated from the power supply so that no power is consumed during stand-by.

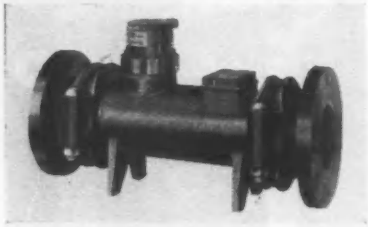
All components are potted for physical and environmental protection, and the switch will operate in ambient temperatures between −65 and 185°F. Six 'One-Shot' switches are available, each with a specific pulse-width in the range 0·1 to 10 μs. These assemblies can produce up to 180 V, and drive loads as low as 5 Ω. Actuation may be push-button or toggle.

Circle **No 532** on reply card

WATER METERS

flow-rates 800 to 200,000 gal/h

Made by Parkinson Cowan, the type-33 water meter is available in four sizes covering flows from 800 to 200,000 gal/h; accuracy is guaranteed to be within ±2% within the recommended flow range. A helical rotor mounted on the meter-body axis rotates at a speed directly proportional to the velocity of flow, and the rotary motion is transmitted to the index *via* reduction gears and a stuffing box. Both gear mechanism and bearings are made from a plastics material to eliminate friction and corrosion. Straightening vanes at the meter



Accuracy ± 2%

inlet prevent turbulence, and a regulator is provided for fine calibration. The meter may be connected directly or remotely to devices such as totalizing indexes, mechanical graphical recorders, etc. Circle **No 533** on reply card

QUICK LOOKS

Wire-diameter gauge. The Addison type-600 wire gauge, operating by capacitance measurement, gives continuous indication of wire thickness. Nominal wire sizes are 0·001in to 0·325in, with sensitivity from 10% for the finest to 1% for thickest wires. Power supply required 100–120, or 200–250V a.c., 50–60c/s.

Circle **No 536** on reply card

Air control valve. A four-way balanced poppet valve for use in the control of double-acting air cylinders is available from Schrader. Pilot pressure required is 15 lbf/in². Two sizes are made: the 825P, with ¼in B.S.P. ports; the 826P, with ⅜in B.S.P. ports. Both are suitable for pressures from 20 to 150 lbf/in².

Circle **No 552** on reply card

Starters. The DOC.80 5 hp starter for three- or single-phase motors is available from A.E.I. Single-phasing protec-

tion is provided on three-phase supplies, and an ambient temperature compensator is incorporated to allow for differences in local temperatures between motor and starter.

Circle **No 537** on reply card

Positive belt drives by Russell Manufacturing (U.S.A.) have teeth spaced to mesh with grooved pulleys, and so provide a positive shaft relationship. Strength ranges from 200 lbf/in width to over 500 lbf/in width. Recommended by the makers for servo-mechanism equipment.

Circle **No 553** on reply card

Flame controller. Ether's series 704 controllers can be supplied for controlling up to six flames at once. Each flame is controlled by a 'flame-eye' comprising a lead sulphide call and a transistor amplifier sensitive to the modulated component in the flame radiation.

Circle **No 540** on reply card

Precision resistors. Now available in the Arcol range are ¼W resistors with values from 1Ω to 1·6MΩ. Made by the Ashburton Resistance Co., the P4 is encapsulated in nylon the colour of which denotes tolerance, the range being from ±1% to ±0·025% in six steps.

Circle **No 560** on reply card

Portable pH meter. Shortly to be available in the U.K. from H. G. Stevens is the G.E.T. battery-operated pH meter. Measuring range is 2 to 12pH, normal accuracy being ±0·1pH. The unit is made like an electric torch, with the electode at the lower end; a Plexiglass cover protects this from physical damage.

Circle **No 555** on reply card

Vacuum switch relay. B. & R. Relays have added the J.55 and J.05 to their existing range. The switches are actuated by the electromechanical operation of the relay, and connexion to the switch is made through a sensitive metal diaphragm sealed inside the glass envelope of the switch. Switching rate is three per second; the relays, which weigh about 8 ounces, will operate in any position.

Circle **No 558** on reply card

Thickness gauge. Daystrom's Xactray consists of an X-ray generator, a pick-up, which converts the transmitted energy to an electrical signal, and an electronic unit which computes and converts the signal for direct meter indication. Dimensional changes are shown as a deviation from the preset nominal thickness, and a signal proportional to thickness deviation is available to operate controllers, recorders, etc.

Circle **No 539** on reply card

Photo-electric detector. Cableform's unit type CF69A consists of a projector head, control unit, and detector head. Sensitivity is such that objects with a width of only 0·01 in are detected at any point along a beam up to 4ft long; minimum width at 10–20ft is 0·025in. The unit will operate from 200–250V a.c., or from a 12 or 24 V battery.

Circle **No 542** on reply card

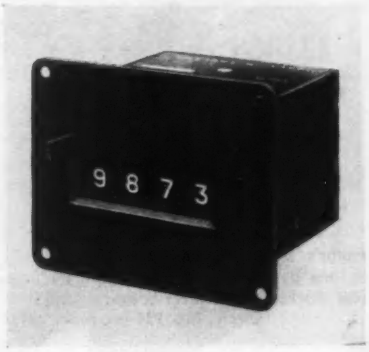
Transistor. S.T.C.'s TK250A is a silicon diffused *n-p-n* transistor for fast switching at currents up to 250mA. Maximum collector-to-base voltage (emitter open-circuited) is 40V, and maximum collector-to-emitter voltage (base open circuited) is 20V.

Circle **No 562** on reply card

Dry reed relays. A life of 20×10^6 operations at maximum contact ratings is claimed for the R01 and R02 d.c.-operated relays from B. & R. Relays. The former, mounted on an eight-pin base, will carry up to three reeds; the latter has a fourteen-pin base and will carry 4, 5 or 6 reeds. Contact resistance is 0·03 Ω, and nominal operating power 0·1W to 0·9W for six reeds.

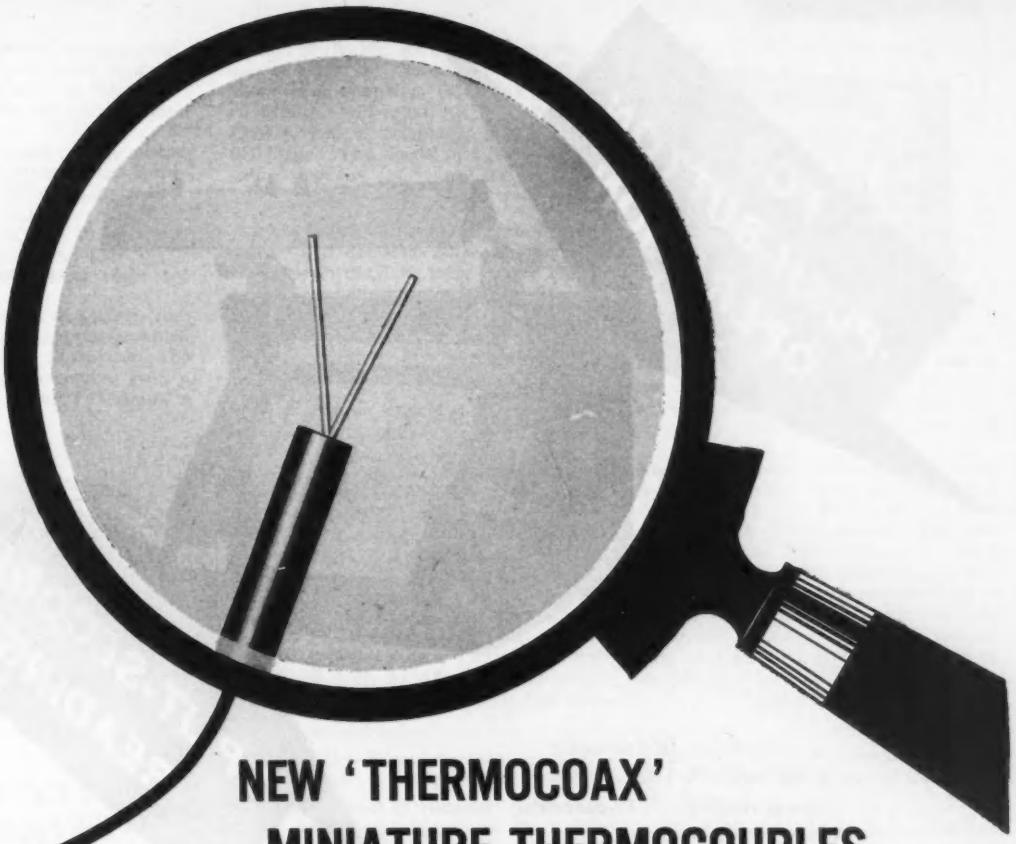
Circle **No 546** on reply card

Electromagnetic counter. With a four-figure display, and either mechanical or electrical resetting, Counting Instruments series-400 counters have been tested at



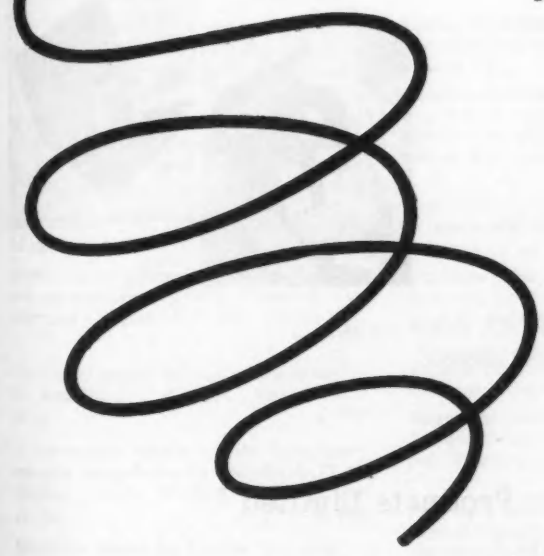
25 counts/s for between 200×10^6 and 300×10^6 counts. The figures are 7/32in high. Both a.c. and d.c. versions are available. Circle **No 550** on reply card

Heavy-duty d.c. supply. An addition to the Gossen range of supplies is now available from Aveley Electric. The unit will operate from a 40 to 60c/s a.c. supply, and has a steplessly variable output range from 5V d.c. at 12A to 66V d.c. at 5·4A. Warm-up time from zero to full load is 0·2ms, and ripple is 1mV. The Constanter supply incorporates an electronically-controlled auto-



NEW 'THERMOCOAX' MINIATURE THERMOCOUPLES

0.25 mm. to 2 mm. outside diameter



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THERMOCOAX miniature thermocouple wires consist of an outer sheath of metal filled with powdered magnesium oxide and enclosing two cores of Chromel-Alumel† insulated from each other and from the sheath. The actual thermocouple is made by joining the two conductors together. Other materials are available on request.*

* *Marque deposee, produce of France* † *Trade mark Hoskins Mfg. Co.*

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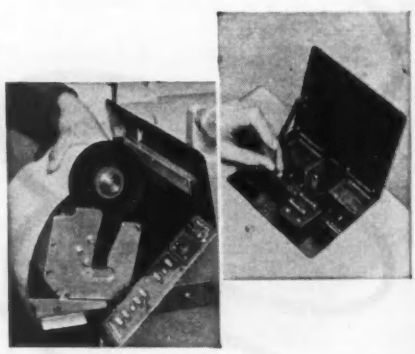

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matic circuit-breaker and thermal overload protection, and will work at up to 30°C ambient temperature at full load.

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Silicon rectifier columns. High-voltage rectifier columns by International Rectifier are capable of delivering up to 1kW per cubic inch of volume. They are available for voltages from 10 to 120kV, with current capacities from 1 to 50A.

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Vacuum/pressure pumps. Available from Edwards High Vacuum are pumps which will deliver completely oil-free air. The 406G, for continuous operation, gives a free air displacement of 1·62ft³/min, a vacuum of 18inHg, and a maximum pressure of 7·8 lbf/in²; the 606G is rated for intermittent operation, delivering air at 1·77ft³/min, will attain a vacuum of 22inHg, and a maximum pressure of 10·7 lbf/in². The weight of either unit is only 10 pounds.

Circle **No 554** on reply card

Audio frequency spectrograph. The Rhode and Schwarz FNA analyser is available in the U.K. from Aveley Electric. Frequency range is 30c/s to 20kc/s, and facilities are provided for both linear and logarithmic indication.

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Precision resistors. Miniature wire-wound resistors, type E, by Alma Components, are available with resistances over the range 100kΩ to 10MΩ. They are wound on ceramic bobbins, and encapsulated to provide hermetic sealing from 0 to 100°C. Tolerance and temperature coefficient are claimed to be ±0·05% and ±0·002%/degC respectively.

Circle **No 567** on reply card

Microvoltmeter. Marconi Instruments TF 1375 a.c. microvoltmeter covers 5μV to 15V in twelve ranges, with a frequency range of 50c/s to 1Mc/s. Input-impedance and sensitivity are such that currents of 10^{-10} A may be detected, making the instrument suitable for use as a sensitive detector for bridge measurement.

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Electronic timers. Britec's ZS11 timer is available in five ranges covering delays from 0·1–1s to 12–120s. Operating voltage is 220 V±15%, 40–60c/s, and contact rating is 220V, 6A a.c. Timing accuracy is ±3% for mains fluctuations within ±10%. Also available is a similar model, the ZS14, which uses an ionization chamber instead of controlling resistors, and gives delay times up to 240 min.

Circle **No 538** on reply card

PUBLICATIONS RECEIVED

A statistical approach to the estimation of design data *by* **A. N. Knowles.** *U.K.A.E.A. Risley. 1961. 26 pp. 3s.* ★ 572

The changing role of electronic components *by* **G. W. A. Dummer.** *Ultra Electric (Holdings) Ltd. 1960. 18 pp.* ★ 573

Memorandum on awards conferred. *The National Council for Technological Awards. 1961. 8 pp.* ★ 574

Group condensation programme for use with Carlson DSN/TDC programmes (IBM 704) *by* **Mrs M. E. Manal and B. M. Segal.** *U.K.A.E.A. Risley. 1961. 23 pp. 3s.* ★ 575

Instruments in the factory. *D.S.I.R. 1961. 12 pp.* ★ 576

Dictionary of automation, computers, control and measuring *by* **W. E. Clason.** *D. Van Nostrand Company Ltd. 1961. 845 pp. £7.* ★ 577

Very small probes for flow measurement *by* **R. Ramshorn.** *U.K.A.E.A. Risley. 1961. 10 pp.* ★ 578

A relocatable version of the Manchester mercury autocode master compiler *by* **D. C. Bindon.** *A.E.E. Winfrith. 1960. 9 pp. 2s. 6d.* ★ 579

Electronic timers by Londex are listed in leaflet No. 190 P 3/61. ★ 580

Chassis-nest. Leaflet No 112 from Bruce Peebles describes their standard chassis-nests which will accommodate up to six plug-in units. ★ 581

'Process control by computer' is the title of a paper by M. James and W. T. Lee reprinted as publication 5115 by de Havilland Aircraft. ★ 582

F.H.P. servo-motors and motor generators are the subject of publication CX.343 from Evershed and Vignoles. ★ 583

Pneumatic equipment by Stuart Davis is shown in their illustrated 39-page catalogue. ★ 584

Squirrel-cage motors. A revised edition of Technical Description No 277 is available from G.E.C. ★ 585

'Liquid metering and dispensing' is the title of a 16-page brochure from Parkinson Cowan Measurement which describes meters for water and industrial liquids. ★ 586

Conveyor and elevator belting is the subject of publication BA 79 from Turner Brothers Asbestos. ★ 587

Transistor diode. The Shockley four-layer transistor diode is described in a data sheet from Brush Crystal. ★ 588

'Electronics' is the title of booklet describing the activities of Bruce Peebles' Electronics Department. ★ 589

Journal of Applied Pneumatics (Vol. 4 No 27), distributed by Martonair, has an article on mechanized compound dispensing. ★ 590

'Survey', issue No 1, reviews the applications in industry of Avery weighing, counting, and testing machines. ★ 591

Frequency and time measurement: Venner's TSA 3336 digital meter is comprehensively described in publication VE 3001. ★ 592

Strobe unit. Dawe Instruments' Variphase Strobe Unit is the subject of their leaflet No 1208. ★ 593

'The telephone in business', a booklet from G.P.O., tells how (and how not) to use the telephone. ★ 594

Electronic counters by Londex are featured in their list No 172/B. ★ 595

Catalogue in Russian, from A.E.I., lists their products to be shown at the British Trade Fair in Moscow. ★ 596

Submerged induction hardening. Delapena's cold-heat gear-tooth hardening machine is described in publication CH 1/60. ★ 597

Counters of every description by Trumeter are listed in their 16-page catalogue No 61/1. ★ 598

Lubrication. An eleven-page illustrated booklet from Castrol describes their two-line centralized lubrication system. ★ 599

'Control for industry' is the title of an illustrated publication from Lancashire Dynamo which reviews their activities in control engineering. ★ 600

Annual reports:

International Tin Research Council. ★ 601

Associated Electrical Industries Ltd. ★ 602

The Electrical and Electronic Manufacturers' Joint Education Board. ★ 603

The British Electrical and Allied Manufacturers' Association Incorporated. ★ 604

★ Circle the relevent number on the reply card facing page 162 for further information

Book Reviews

Protection

The Relay Protection of High Voltage Networks *by* **G. I. Atabekov.** *Pergamon Press Ltd. 1960. 564 pp. £4 4s.*

This is a theoretical monograph covering electrical protective gear. It is an exposition of the methods of theoretical analysis, many of them developed by the author, which enables the reader to develop these methods for himself. Professor Atabekov is an outstanding professional engineer who has been awarded a Stalin Prize for his work. This book is the essence of a lifetime's study in this field.

Two adjacent disciplines are combined in this work. These are the technique of relay protection and the theory of the calculation of short circuits, two subjects which are often treated separately.

The author has extended the theory of asymmetrical abnormal conditions, and his application of equivalent networks makes his analysis graphic. The circle-diagram method which is described at length, is an extremely important contribution to the subject, especially for distance protection, and may well find application in other fields. The following topics are discussed: sequence networks for complex asymmetrical states, the vector locus method as applied to relay protection of high-voltage transmission systems, theories of symmetrical components filters and power directional devices and the principles of construction and methods of theoretical analysis of the operation of transmission line and busbar protection (distance, high voltage, differential and others) in balanced and unbalanced states. The theoretical questions are examined in the light of present-day practical problems in relay protection of high-voltage networks with three-phase and single-phase tripping.

This is a unique work, invaluable to western scientists, not only for its excellent content, but as an indication of current Russian thought and progress in this sphere. DENIS TAYLOR

Terminology

Elsevier's Dictionary of Automation, Computers, Control and Measuring. *Compiled by W. E. Clason. Elsevier Publishing Co. (distributed by D. Van Nostrand Co. Ltd). 1961. 848 pp. £7.*

The best test for a technical dictionary is intensive use over a fair period of time, but it is still possible to assess with some confidence the possible future value of a new one. If there are many entries, that raises the probability of finding a given word among them; and the average length of the entries indicates how much detail there might be in each of them. Another criterion is presentation: clear print on good paper in a practical binding obviously enhances the value of a reference book. Finally, there are usually some terms that one knows already, and by sampling their definitions in the dictionary one can infer the quality of the rest.

Elsevier's dictionary has 3390 entries. The terms all run on alphabetically, but a subject classification (e.g. *control, electronic computers, mathematics, automation*) appears against each term. Around twenty to thirty words of English definition follow the subject classification, and after that the equivalent of the term itself in French, Spanish, Italian, Dutch and German respectively. An alphabetic list of terms is given for each language separately, and a thumb index leads one easily to the list required. The general presentation of the book is very good.

The sampling test is bound to be rather a personal one, and report a few of my results with the obvious reservations. I find AUTOMATION defined as 'The entire field of investigation, design, development, application and methods of rendering processes or machines self-acting or self-moving; rendering automatic, theory, art or technique of making a device, machine or process or procedure more fully automatic; the implementation of a self-acting or self-moving, hence, automatic process of machine'. The subject classification is given as *automation/electronic computers* and *control* is not mentioned. On the other hand, AUTOMATIC CONTROL *is* classified under *control* but apparently has nothing to do with *automation*. CONTROL ENGINEERING (*Control*'s distinguished American contemporary will be sad to learn) does not enter the subject of *automation* either. In spite of all this, CONTROL itself is 'The method and means of governing the performance of any apparatus, machine or system'. CYBERNETICS is defined as the comparative study of control etc. in machines and men, but its subject classification is *automation/electronic computers* and *control* is not included. BLOCK DIAGRAM, according to this dictionary, is a term used in the subject of *electronic computers* and means 'a schematic diagram representing the functions of the machine': DEPENDENCE DIAGRAM does not appear. Nor does ADAPTIVE or SELF-ADAPTIVE or SELF-OPTIMIZING; but OPTIMIZING is said to mean 'To space instructions or data around the drum stor(ag)e so that the information is in a position to be accessible when needed'. A CONTROLLER governs the delivery of electric power, according to definition 645, but definition 2275 is of a PNEUMATIC CONTROLLER and this appears to have application to a broader range of variables. A SERVO-MECHANISM would not, on the definition given in Elsevier, be immediately recognizable as having anything to do with position control or speed control. SYNCHRO is defined, rather too vaguely I think, as 'An electrical system for remote control or indication'.

I should advise the general user to browse through this dictionary himself before deciding whether to buy it. To the control engineer concerned with technical literature in the various languages, the book may well prove invaluable. A.E.E.

Instrumentation

Fundamentals of Digital Instrumentation *by* **D. S. Evans.** *Hilger & Watts Ltd. 1960. 39 pp. 7s. 6d.*

This monograph is not quite so comprehensive as the title might imply. It deals with the rudiments of electromechanical shaft-position digitizers and decoders, and briefly outlines particular methods of sampling, storing and print-out. In parts clarity has been sacrificed to brevity, but for those who require a brief introduction to the subject this booklet will fulfil its purpose. The format and cloth-lined board covers are unusual but not unpleasing. R. E. FISCHBACHER

Physics

Introduction to Modern Physics *by* **C. H. Blanchard, C. R. Burnett, R. G. Stoner** *and* **R. G. Weber.** *Pitman, London: Prentice-Hall, New York. 1960. 420 pp. £1 17s. 6d.*

This book was written to put over atomic physics to American engineering students, and it does so in delightfully untrammelled language (the American usages are scarcely a disturbance). The authors know precisely what they want to teach, and do not let themselves be side-tracked: for example, they say at the beginning that they will use rationalized m.k.s., and they refer the unfamiliar reader to other sources for explanation and discussion of units. The work cannot therefore be regarded as a complete and self-contained text. As a survey for students with sufficient background, however, it is excellent, covering the range from macroscopic to microscopic physics through the usual phases, and introducing quantum mechanics, electronic structure of atoms, solid-state physics, relatively, and finally nuclear physics in its various ramifications. The book is very well produced and easy to read. A.E.E.

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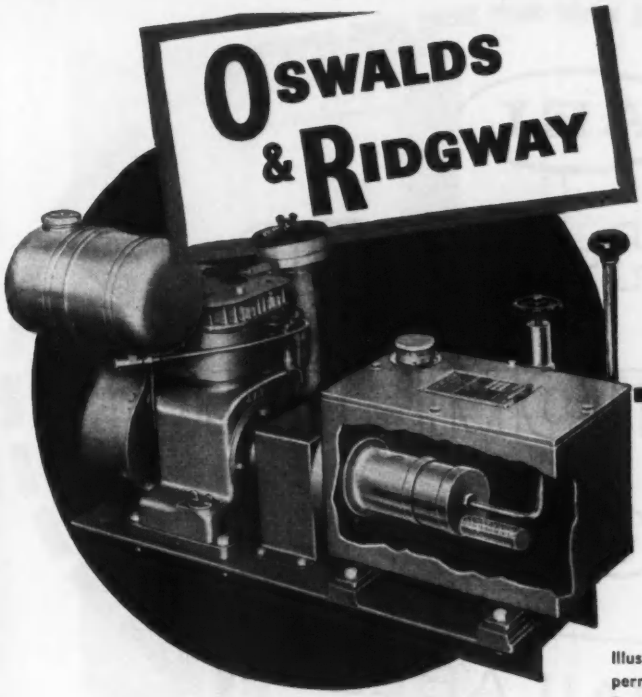

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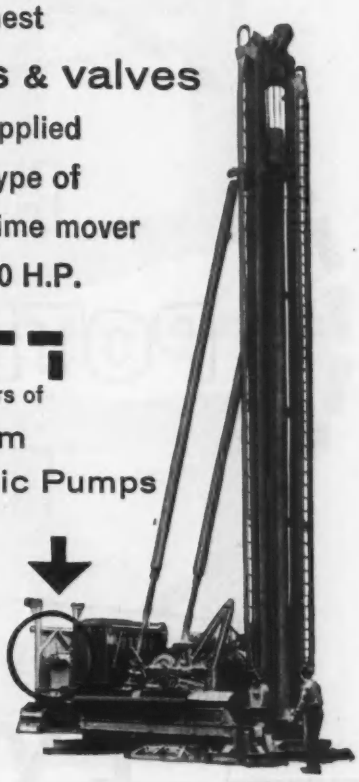

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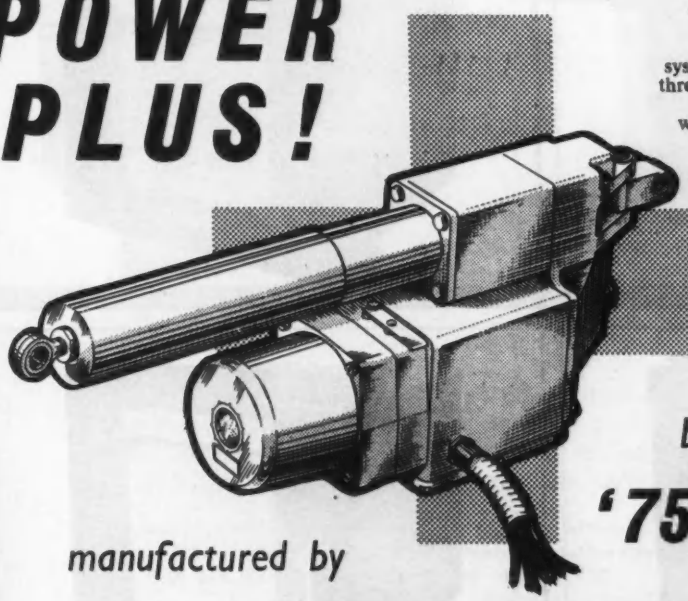

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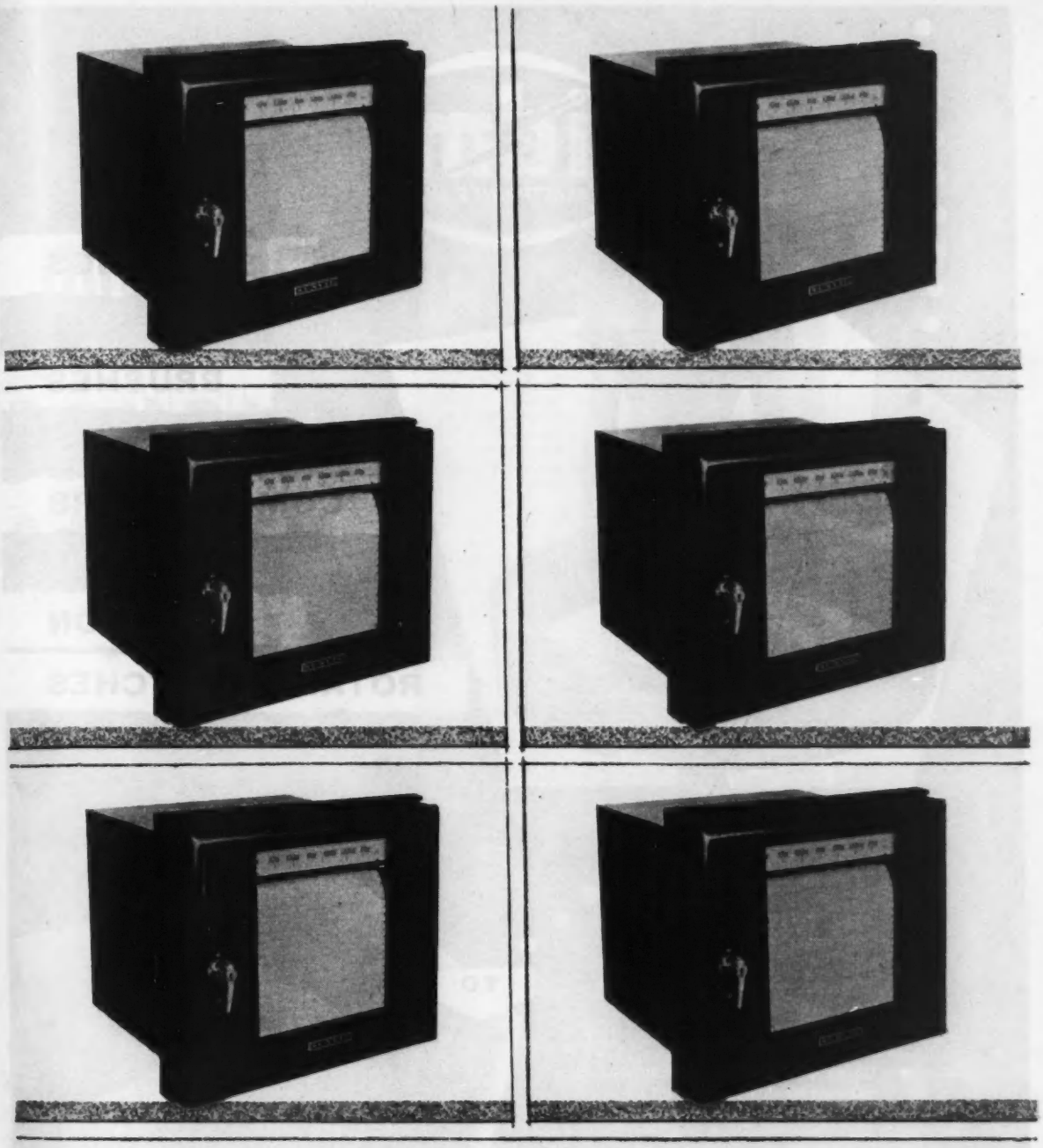

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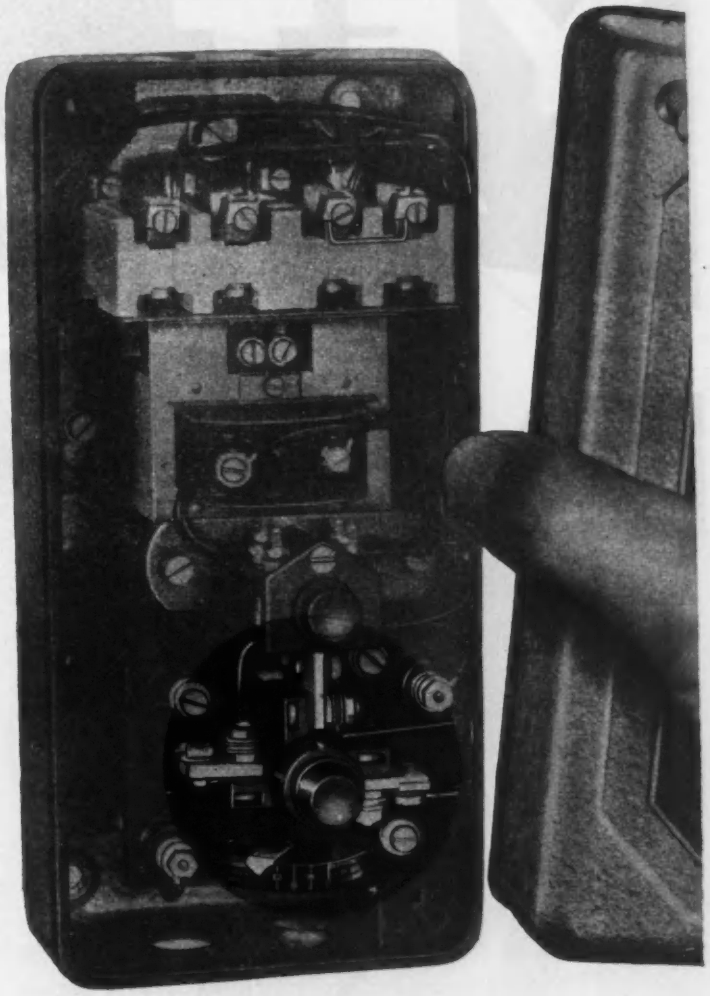

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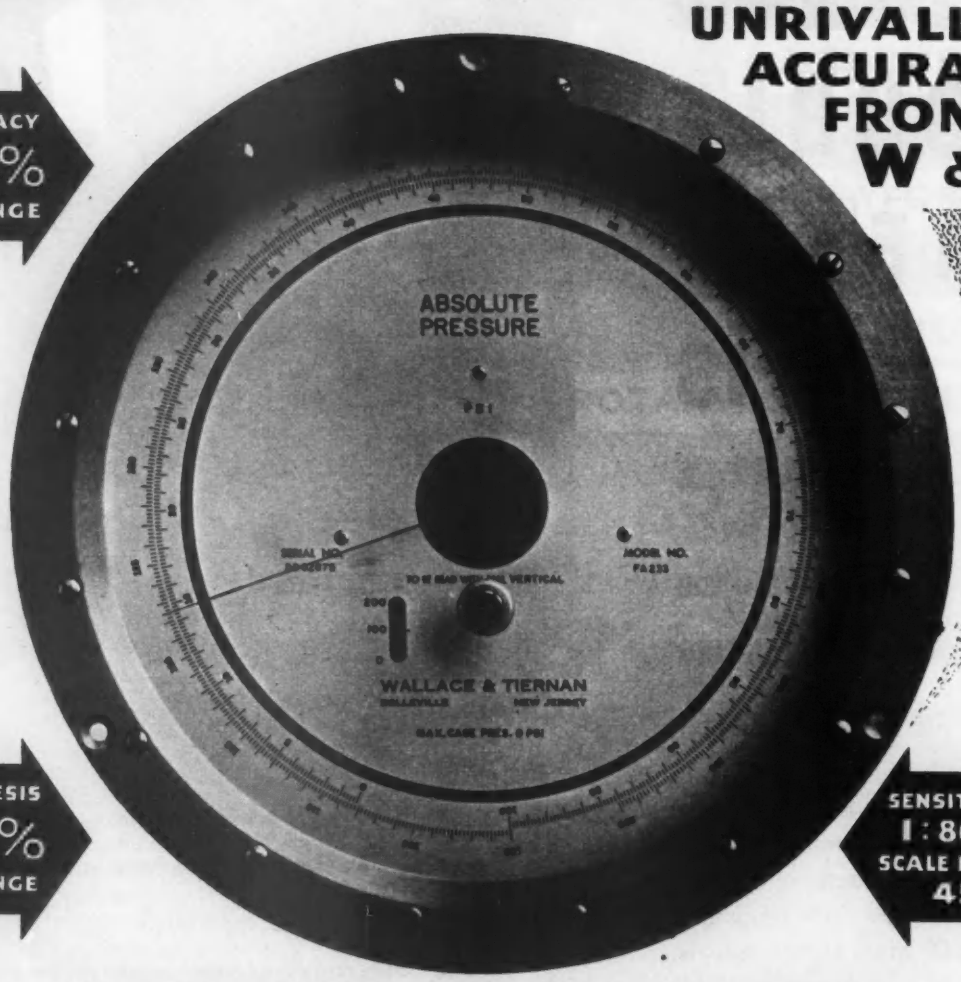

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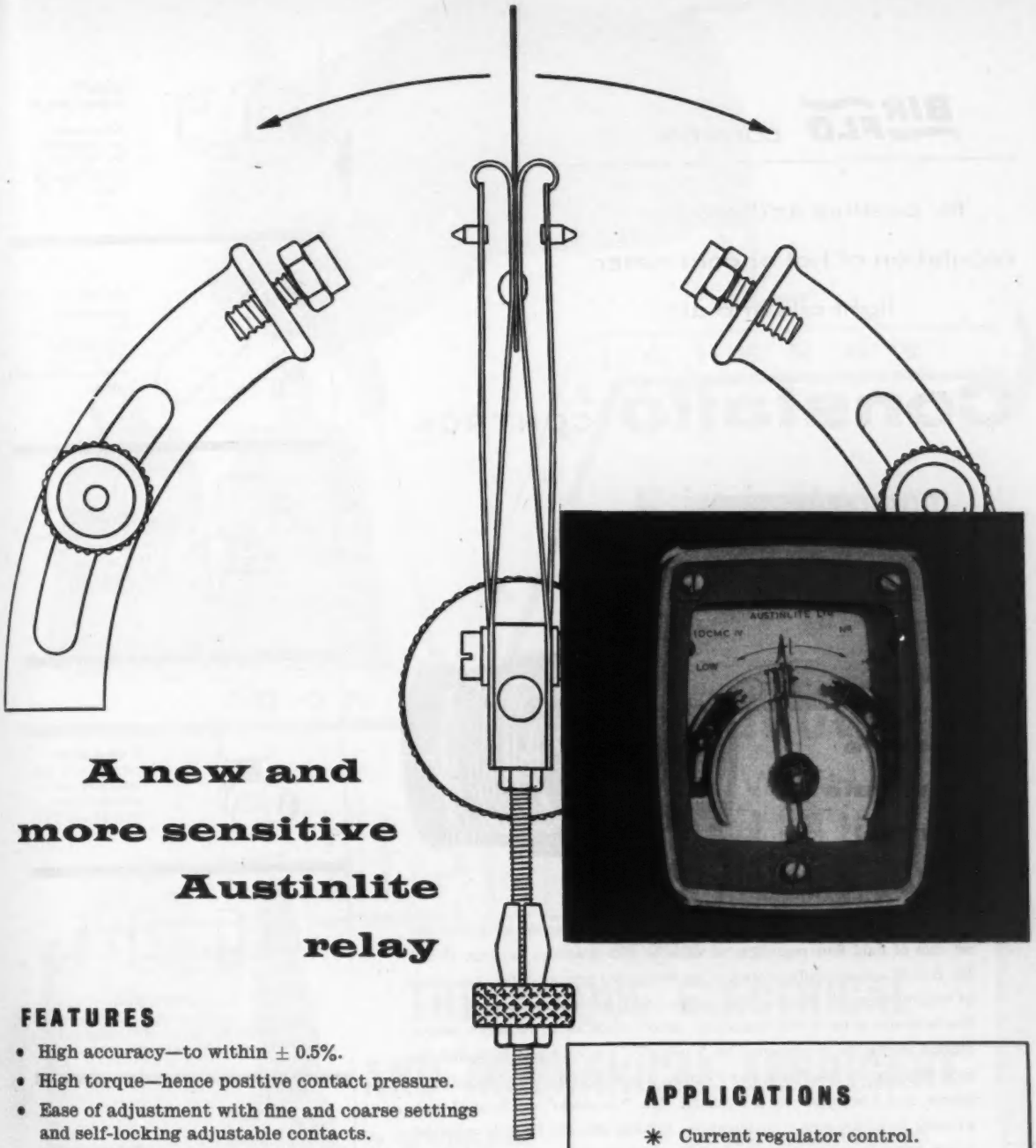

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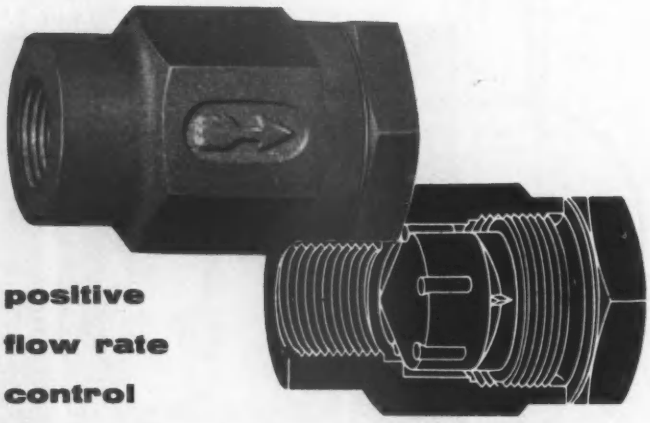

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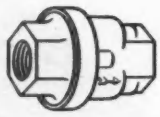

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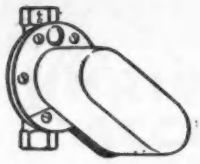

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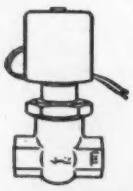
For positive flow-rate control with minimum (0·1 g.p.m.) or maximum (40g.p.m.) limits.



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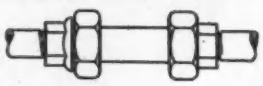
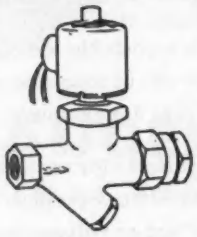
A solenoid valve for maximum flow rates. Sizes up to 1¼" B.S.P.

FLOMITE
A direct action solenoid valve for small flow and volume control. Sizes ¼" and ⅜".



STRAITFLO
A straight line strainer, installed in the supply, having the entire strainer area within the flow way itself. Sizes up to 1¼"



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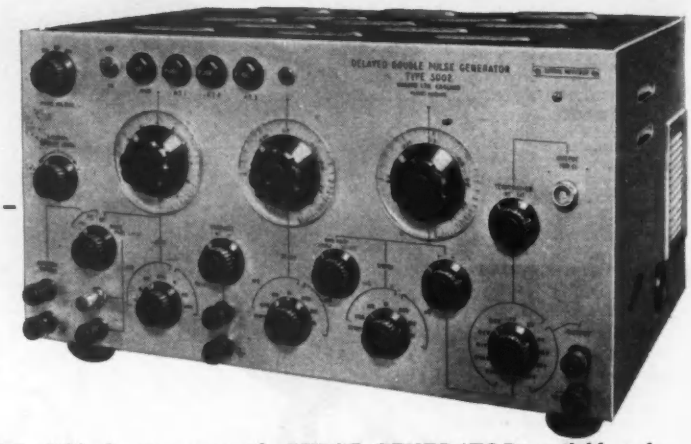

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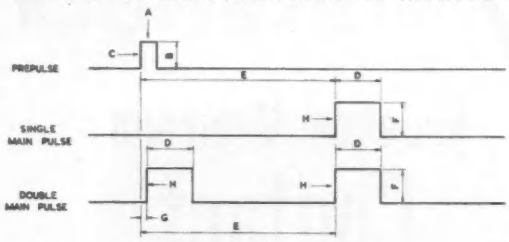

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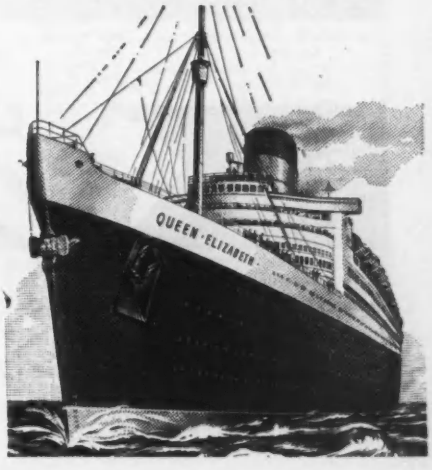

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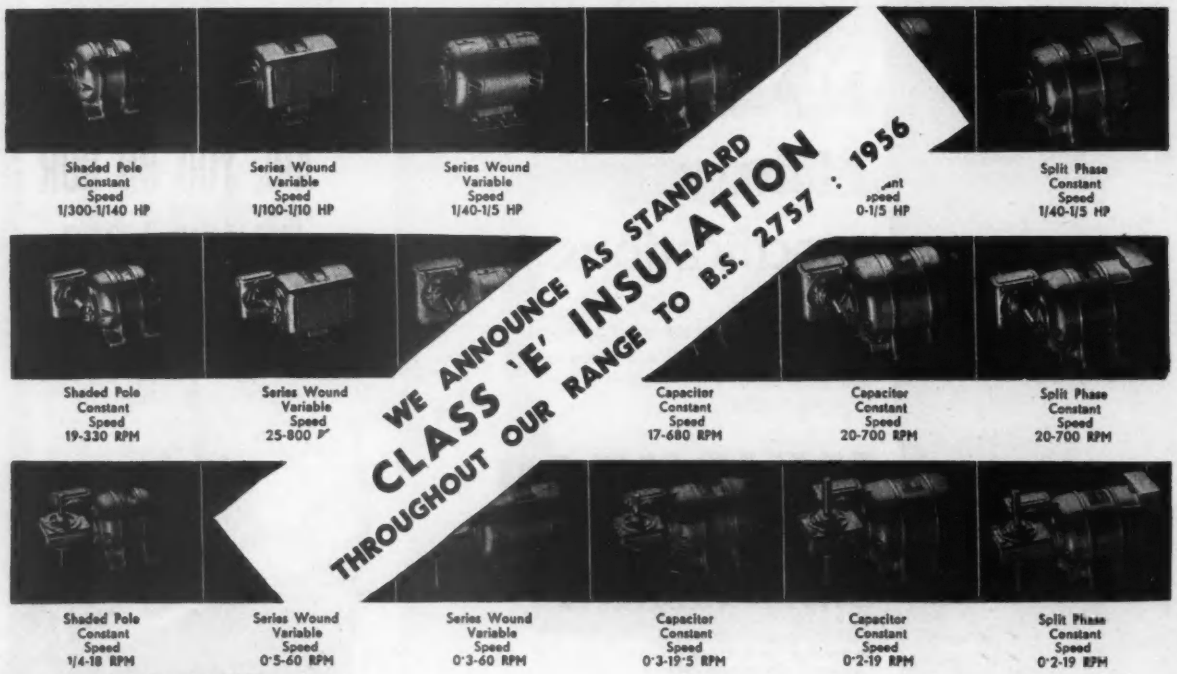
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Insulance	10^6M Ω	10^6M Ω	20,000M Ω /μF or 50,000M Ω whichever is the less	20,000M Ω /μF or 50,000M Ω whichever is the less
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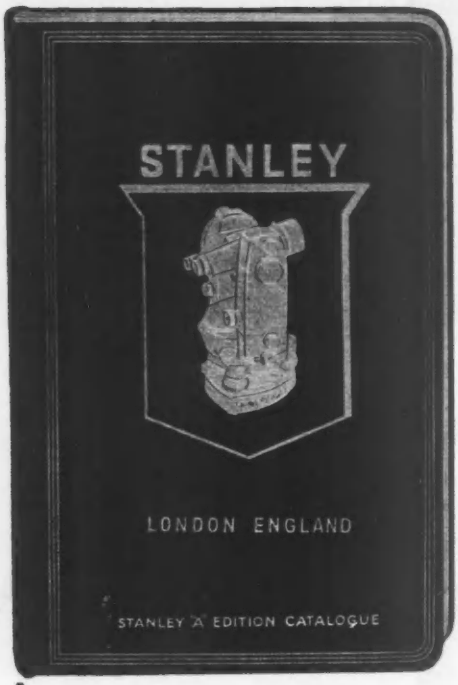

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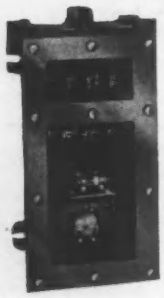

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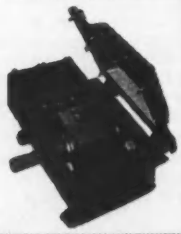

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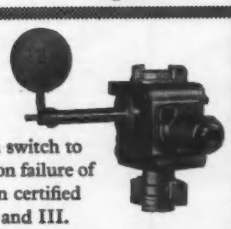

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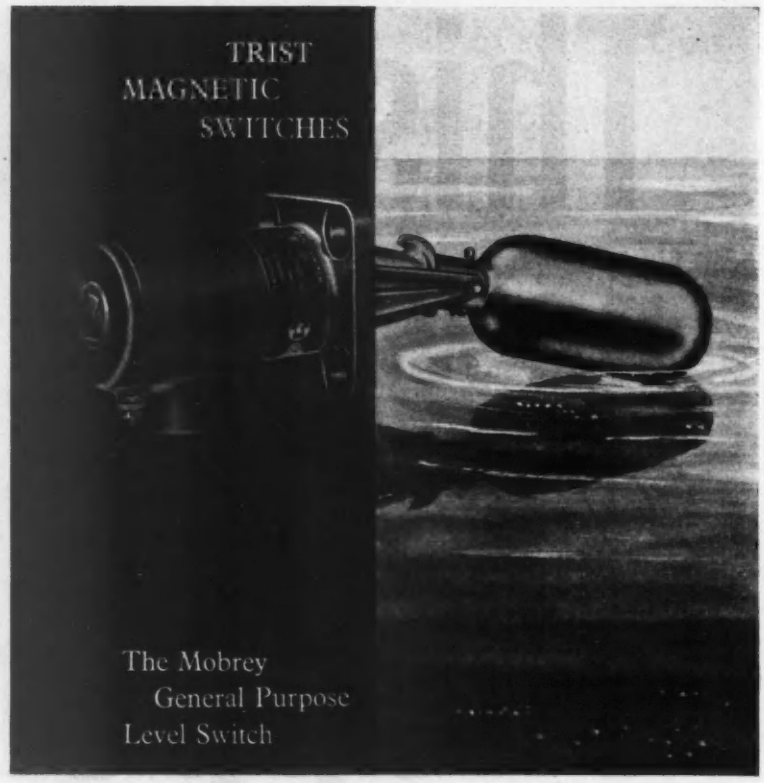

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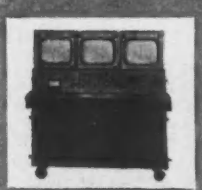

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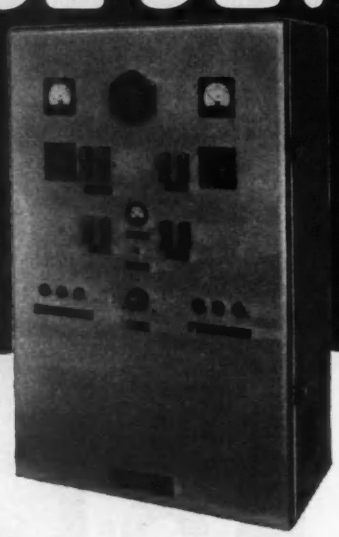

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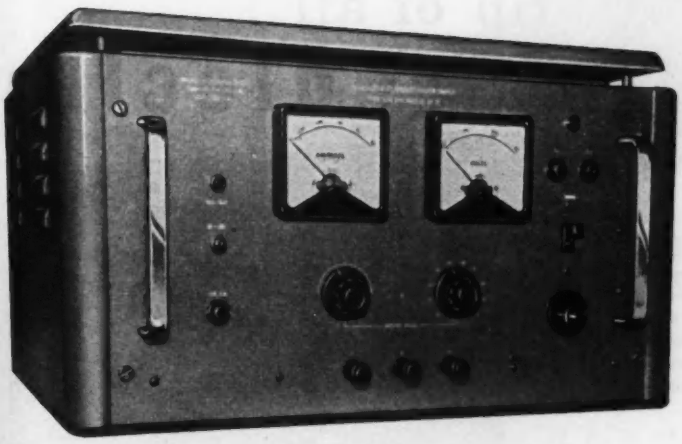

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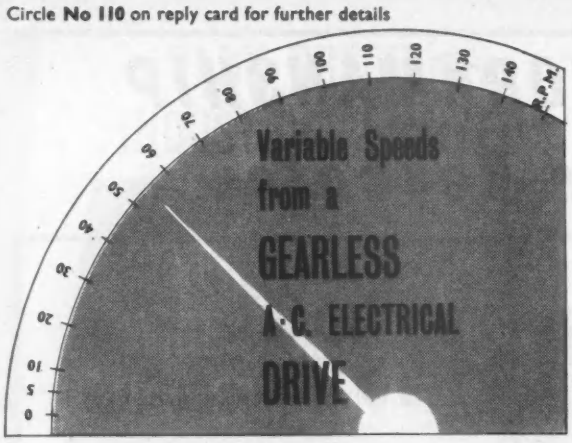
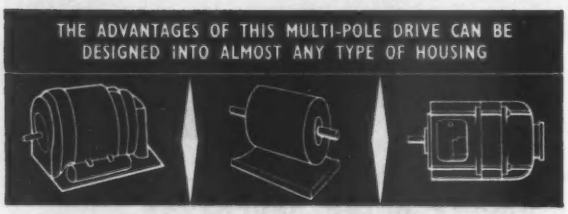


Resultant from recent developments the Nelson Hetropolar Motor is now available as a unit permitting variable speeds, (5 to 140 r.p.m., according to the standard unit used), from variable frequency inputs. (Suitable V.F. Rotary Alternators and contol gear can be supplied). Where operated from fixed frequencies, the speed range has been increased to provide a GEARLESS electrical drive of 62.5/75/93.75 r.p.m. at 50 cycles or 75/95/112.5 r.p.m at 60 cycles.

Power/Dimension ratio is favourable, torque output is constant and stopping, starting or reversal is instantaneous, (full synchronous speed reached in less than half a cycle). During operation, the locked rotor current does not exceed the full load; the motor, therefore, cannot burn out and is suitable for continuous duty. Maintenance is reduced to a minimum since there is only one slow moving part and bearing wear is negligible. It is self starting (direct switch) and can be used with any A.C. Voltage, (suitable low voltage transformers can be supplied *).

Hetropolar Motors can be used with SELSYN or Sinusoidal Wave Interpretation Equipment and are being applied to indexing, valve, cam or rheostat control, digital computers, etc.

**** The Nelson Engineering Co. Ltd. are specialists producers of non-standard static or rotary electrical equipment and are always pleased to discuss this in relation to prototype requirements.***



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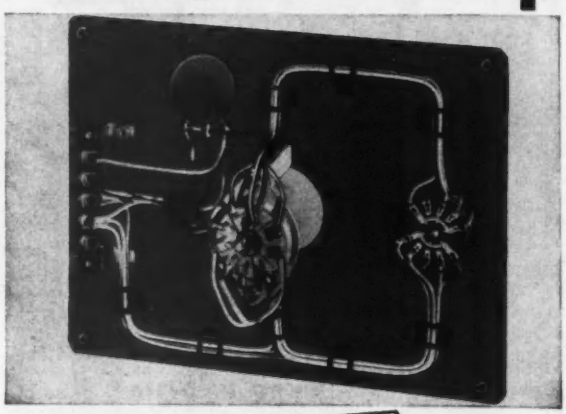
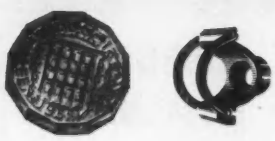


miniature Insuloid cradleclip



Comparison with a three-penny piece gives some indication of the very small size.

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WITH ALL THESE ADVANTAGES

- ★ **Cuts wiring time by 52%.**
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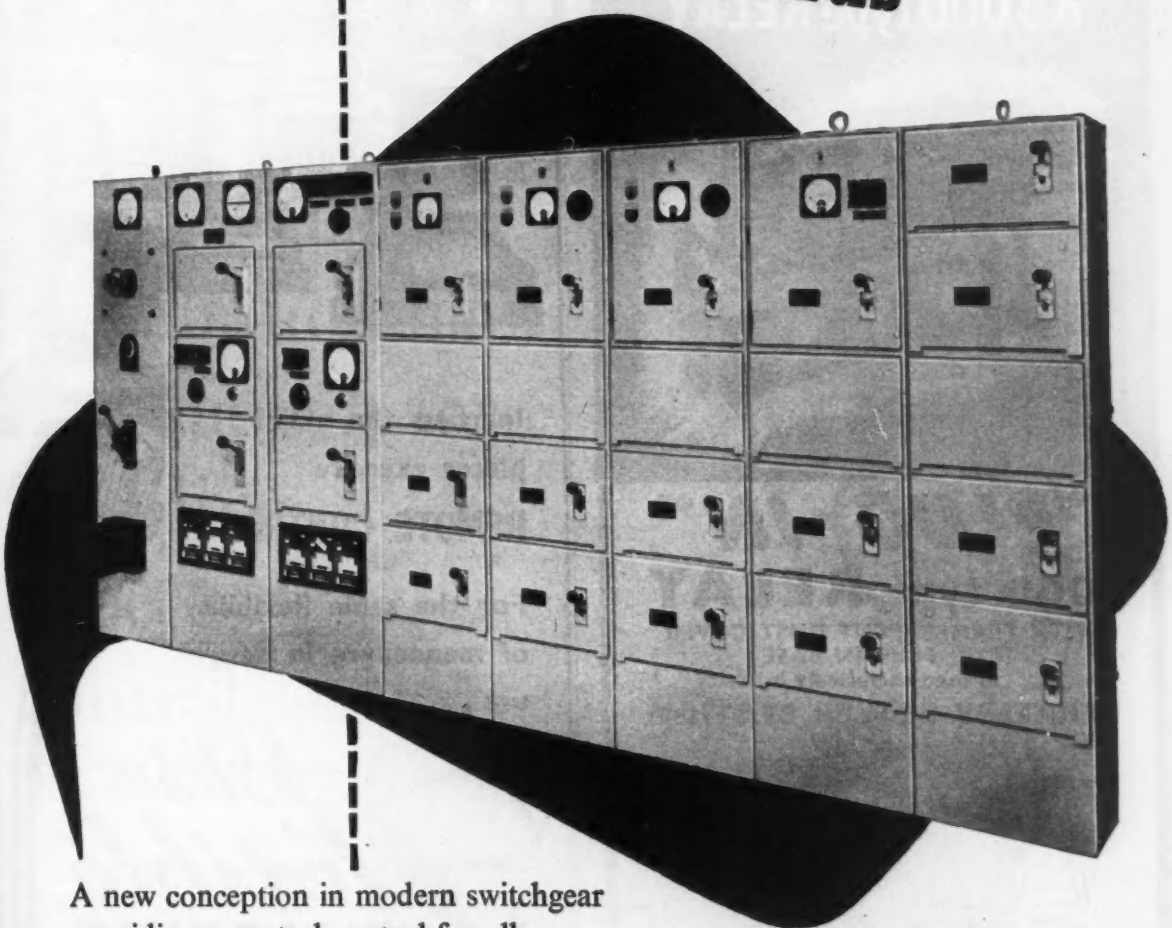

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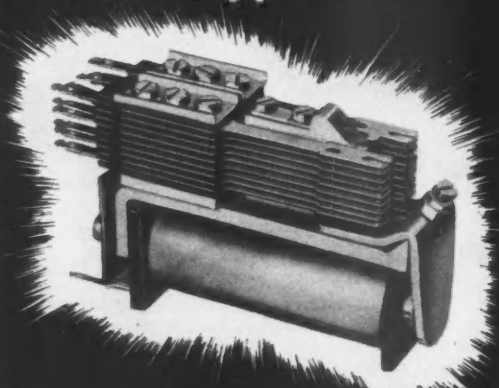

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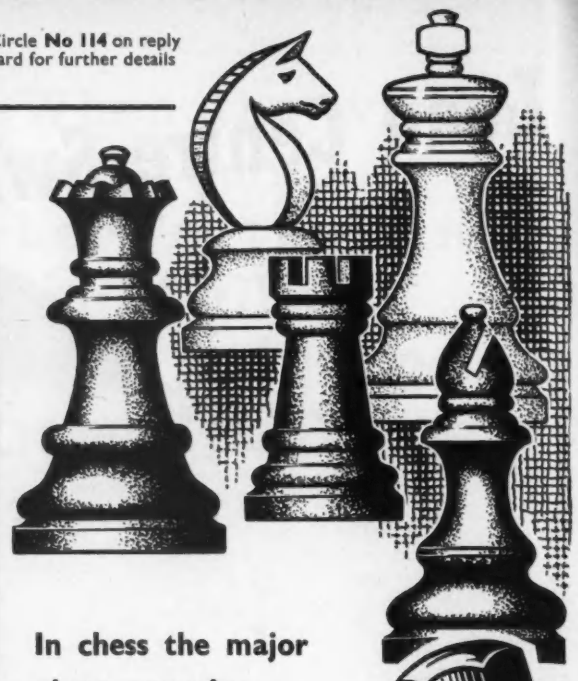

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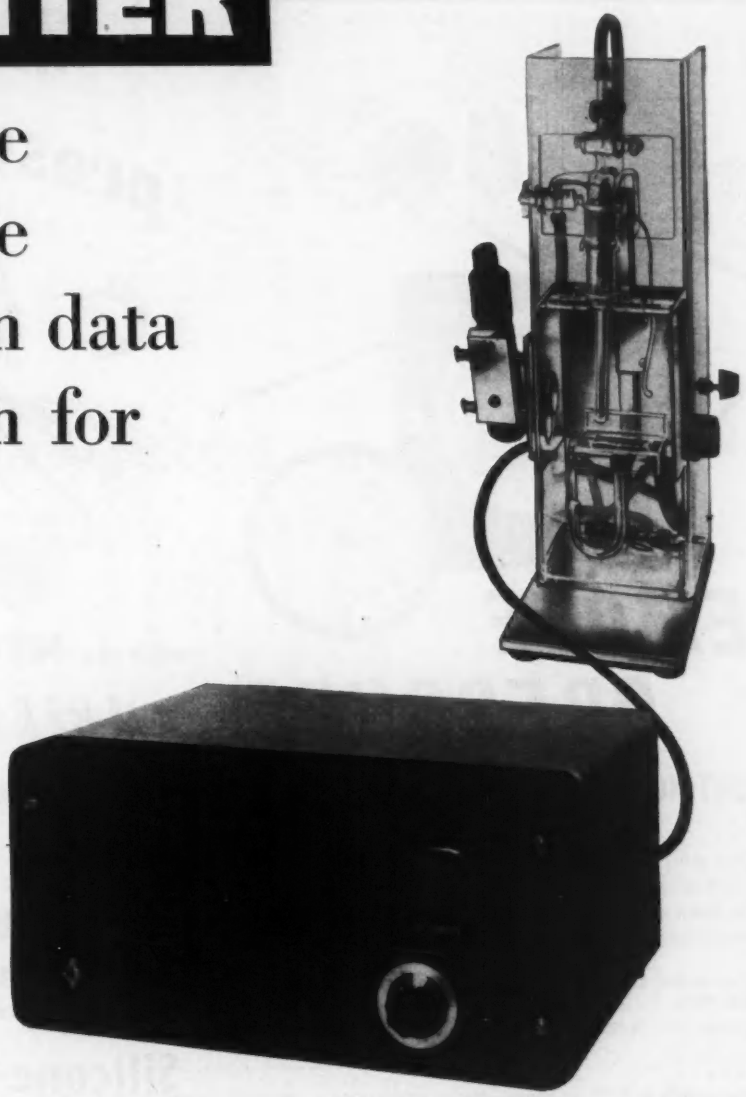

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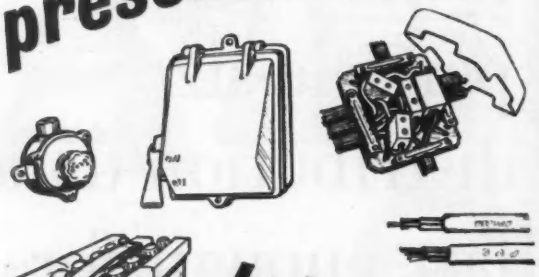

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PROBE MKT 12 for walls, windows, floors, radiators, pipes. The sensitive element is flexible and adopts entirely the shape of the object to be measured.

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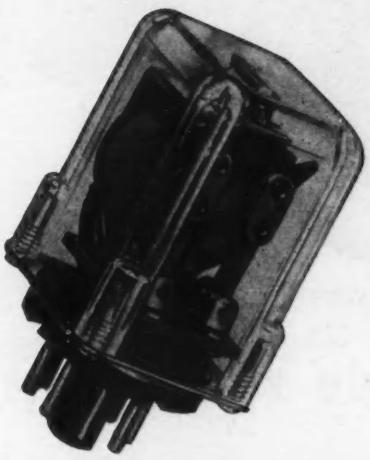

New interchangable relay designed for use in remotely controlled automation units. Has double pole changeover contacts.

Dust proof—transparent plastic cover.

Plugs into any standard International octal valve base.

Weight Only 4½ ozs . . . projection only 2" above base.

Mechanical life over 10,000,000 operations.

Switching current: 5 amps maximum at 250 volts A.C.

Maximum surge current: 10 amps.

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Release time: 6 milliseconds approx.

Overall dimensions: 1⅞" square by 2$\frac{9}{32}$"

Coil voltage: 240 volts standard; also available for 6, 12, 24, 48, 60, 110 volts

Thorn T9 Micro-Switch Relay

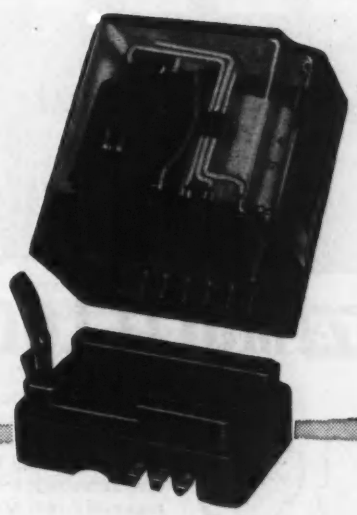
A plug-in relay, particulary suitable for switching P.A. equipment, the snap action contacts minimising interference with pick-up leads.

Operating coil wound for any specified voltage up to 240 volts A.C. or 150 volts D.C. May be tropicalised.

Up to three micro-switch pattern contacts mounted on standard coil frame.

Versions available with up to 11 solder tags or 10 screw terminals.

Contacts:	3 changeover.
Mechanical Life:	Over 10,000,000 operations.
C/O Time:	C.O. period less than 2 milliseconds.
Max. Switch:	10 amps/240 volts A.C. non inductive load.
Capacity:	0.2 amps/240 volts D.C. „ „ „ 0.5 amps/110 volts D.C. „ „ „ 1.0 amps/50 volts D.C. „ „ „ 5 amps/24 volts D.C. „ „ „
Max. Operate Speed:	20 cycles/sec.
Switching:	Up to 0.1 amp. approx. 20 cycles/sec.
Frequency:	„ „ 1 „ „ 5 „ „ „ „ 5 „ „ 1 „ „ „ „ 10 „ „ 0.1 „ „ (referred to A.C. non-inductive load).



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THORN ELECTRICAL INDUSTRIES LTD · SPECIAL PRODUCTS DIVISION
(incorporating Components and Connectors), Great Cambridge Road, Enfield, Middlesex. ENFIELD 5353

DTV/15

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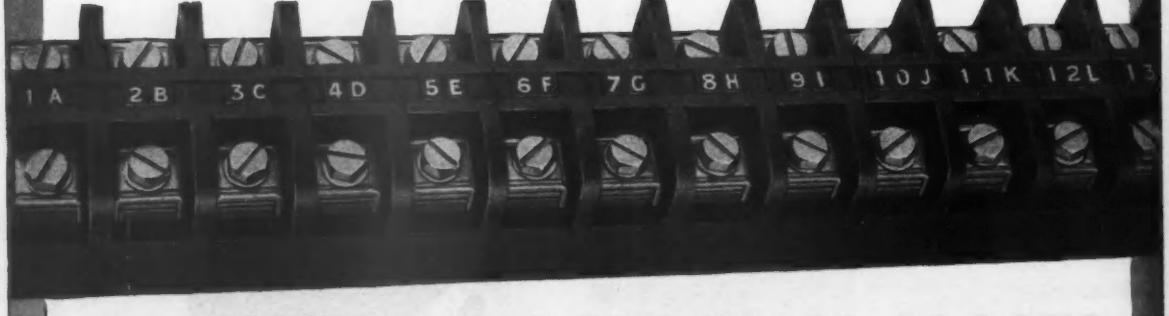
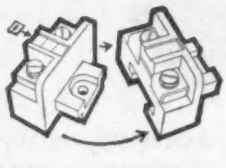


MTE MULTI-LOCK TERMINAL BLOCKS



With Multi-Lock you can build up complete terminal block assemblies consisting of any number of single units you choose. They are available in three ratings (15, 40 and 100 amp.) and can be mounted to any surface without special brackets or channels. The 40 amp. and 100 amp. blocks also interlock with one another to give two different ratings in one assembly. All Multi-Locks meet B.S.I. and C.S.A. specifications.

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The I.S.I. 609 for a large Chemical Works. Shown are the five basic elements of the system.

1. Elliott 803 Digital Computer (Channel 1).
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offers **9** *unique advantages*

★ **60%–70% of Computer Time Free for OFF-Line Work.**
On-line operations rarely demand more than 30%.

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★ **Monitoring of Process Variables.**
Automatically records and audibly signals all off-normals.

★ **Fast Arithmetic.** Special unit operates on all process data in 2.8 milliseconds—even for square roots, a tedious operation in other computers.

★ **Continuous Logging of Process Inputs**—with all off-normals clearly indicated in red.

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★ **Automatic Plant Control.**
Automatically re-sets individual control loops to the optimum level.

★ **Analogue-Digital Conversion**—and vice versa.

★ **"Routine" Changes Without Interrupting Operation of System.**
The number of index registers for this purpose (most computers have very few) is almost *unlimited*. Programming of extremely complex problems is thus enormously simplified.

The use of solid-state components throughout plus continuous self-checking routines and fail-safe circuits make the Panellit I.S.I. 609 System the finest in the world and the ultimate choice of every discerning engineer. Our specialists will be pleased to call on you to discuss its application to your own work.

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P8

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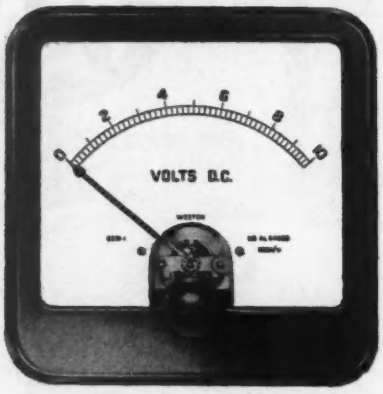
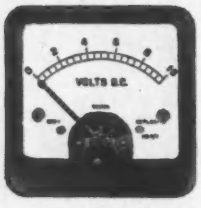
WESTON

moving coil panel Instruments

are now available with SQUARE FRONTS

Complementary to the existing ranges of round, rectangular and edgewise instruments, this new series has been introduced for use on equipment where square fronted instruments are preferred.





3 sizes are available with flange dimensions of 2.25", 3.187" and 4.50" square.
For further particulars including ranges, write for details of Models S.219, S.220, S.221 and S.236.

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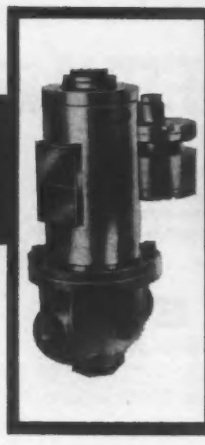
Tel: Enfield 3434 (6 lines) & 1242 (6 lines)
Grams: Sanwest, Enfield



For the positive control of all types of liquid or gases, a wide range of valves has been developed to meet the many industrial applications, e.g. test rigs, flow control, materials handling, interrupter gear. The range includes rectifiers and valves for working pressures up to 6,000 p.s.i. Many of these components are covered by Buxton Flameproof certificates. Valves can be supplied to meet any special applications. We invite you to discuss your project with us.

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ELECTRO-HYDRAULICS LIMITED
INDUSTRIAL SALES DEPARTMENT
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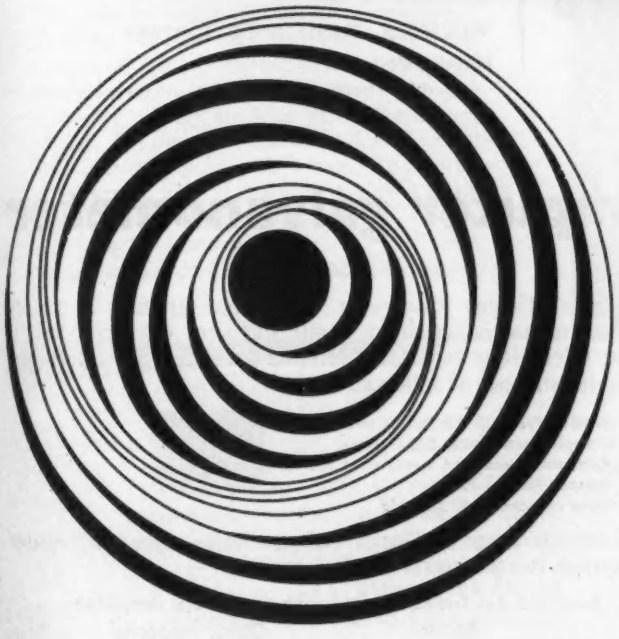

The transducer fixes through a single one inch diameter hole and when brought into close proximity with any ferrous irregularity on a rotating shaft will produce a pulse.

The output can be fed into a suitable electronic counter with or without amplification. Direct readout in r.p.m. can readily be obtained by the use of simple ancillary equipment details of which we will be happy to supply.

For more detailed information please write to
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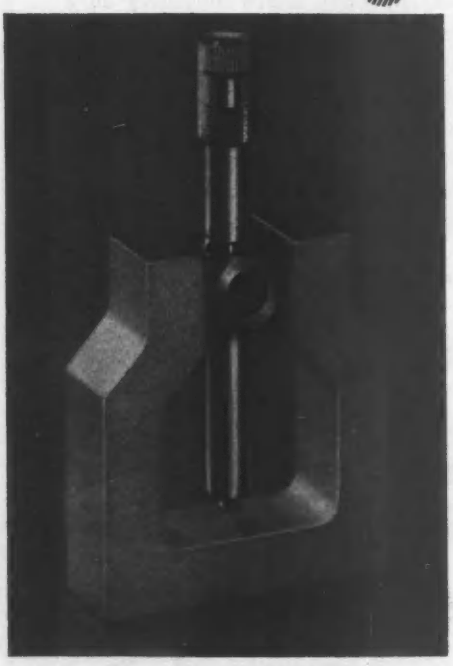
Tinsley computer galvanometer



The new Tinsley Computer Galvanometer has a highly efficient magnetic circuit, a small and very light coil and is liquid filled. It is especially suitable for step recording. The characteristics are as follows :—

Sensitivity: 3420 mm/μA at one meter scale distance
Damping resistance: 60000 ohms
Zero shift: less than 1 mm after 500 times overload
Balance factor: 30
Time constant: 140 seconds

The complete range of Tinsley Galvanometers covers all possible applications in experimental work. It includes: —

Sensitive d.c. Galvanometer with or without Amplifier
Ballistic — **Quick response**
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For details of galvanometers to meet your specific requirements, write to:—

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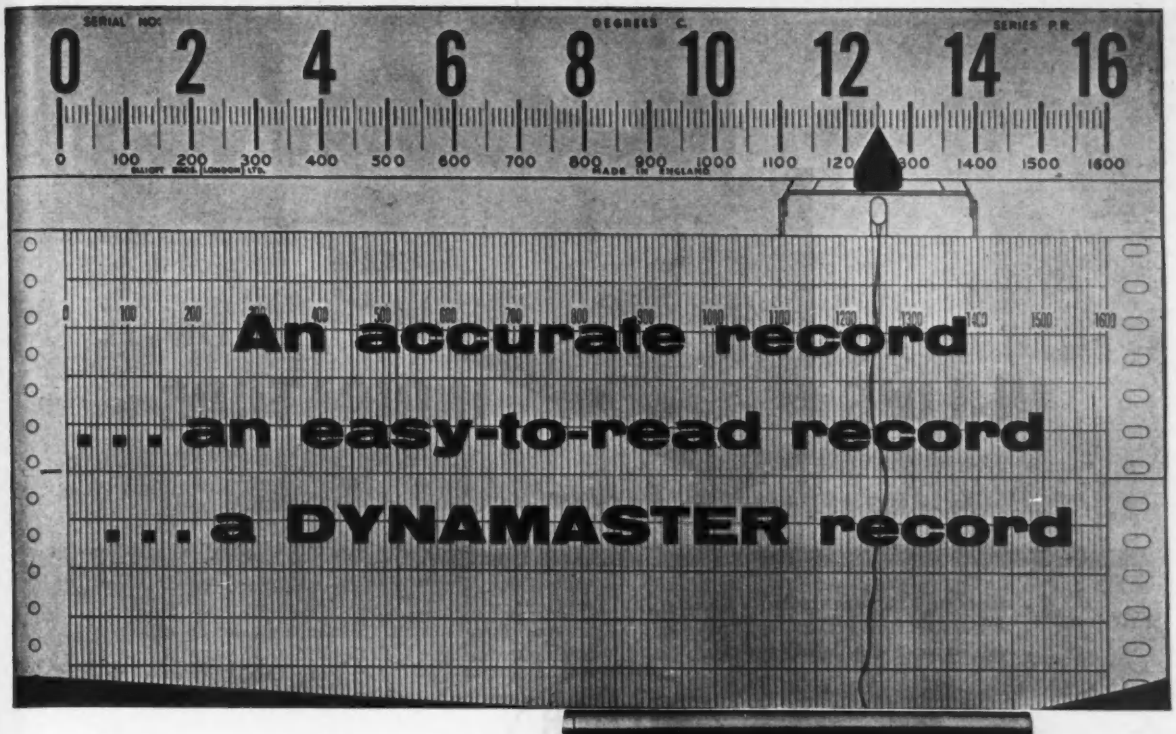
Werndee Hall, South Norwood, London, S.E.25
telephone: ADDiscombe 6046-8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. . . an easy-to-read record
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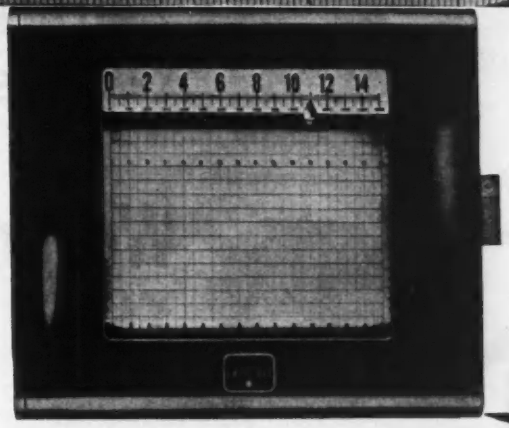
From one to twenty-four *accurate* recordings – on an easy-to-read strip chart that is 12¼" wide – with an instrument that combines fast response, sturdy construction and superb design-simplicity! These are some of the advantages behind *Dynamaster's* reputation for efficiency in industrial plants, pilot plants, laboratories and research units. Let us tell you more about Bristol's Dynamaster – available as a self-balancing potentiometer or as a bridge instrument for dependable recording or control.



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DYNAMASTER POTENTIOMETER
controls and/or records quantities that can be measured in terms of D.C. voltage or current.

DYNAMASTER BRIDGE
controls and/or records variables which are a function of resistance or capacity.

- *Continuous measurement.*
- *Few moving parts.*
- *Wide chart and boldly-figured indicating scale.*
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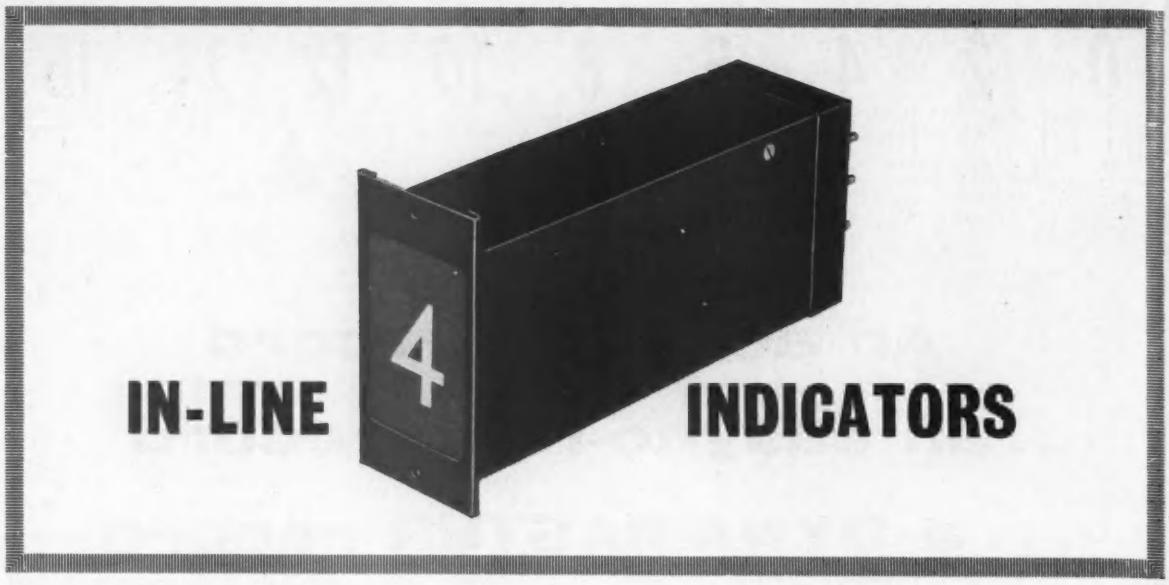

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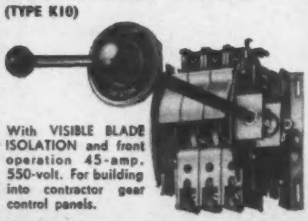
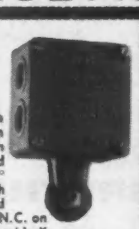
CONTROL ACCESSORIES

LOAD-BREAKING ISOLATING SWITCHES (TYPE K10)



With VISIBLE BLADE ISOLATION and front operation 45-amp. 550-volt. For building into contractor gear control panels.

LIMIT SWITCHES (TYPE C32L 810/1)



Plunger pattern with roller on end. Roller can be moved through 90° and the switch can be altered from N.O. to N.C. on site. Box: 2⅛" wide X 2⅛" high. Plunger: 1⅛" C.S.A. approved.

TERMINAL BLOCKS (TYPE J96)

Clamp-type terminals. White marker strip, generous clearances between phases and to earth. 15 & 30-amp. 660-volt. 3 and 4-way. C.S.A. approved.

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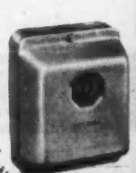
Available 2, 4, or 8-pole (with one or two coil circuit change-over contacts rated at 15-amp. 550-volt. Any pole can be N.O. or N.C. Available C.S.A. approved. Illustrated is a 4-pole enclosed relay.



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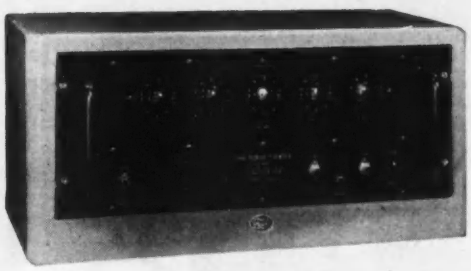
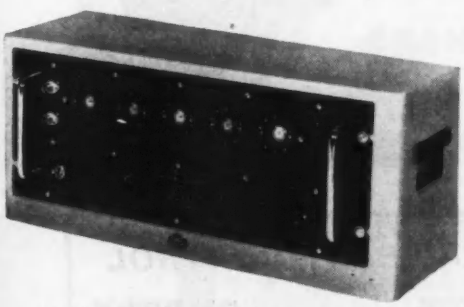
decatronics*.....!

A complete range of Instruments for Pulse Counting and Timing



D.4108 Time-Period Counter for measuring short time intervals between events.



D.4131 Fast Counter for general industrial and nuclear pulse counting.

D.4139 Timing Control Unit for pulse counters for tachometers, etc., variable count and read-out times.

To meet the needs of a widening variety of counting and timing functions involved in many industrial processes to-day, Labgear Ltd. offer a range of instruments which combine laboratory accuracy with practical "workshop" reliability. Labgear engineers have devoted special attention to advances in circuit techniques, with the result that each instrument embodies special features and provides facilities for versatility in use.

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D.4102 TIMING UNIT, a mains frequency timer for nuclear scaling units for "time per unit counts" and "counts per unit time" operation.

D.4127 PROGRAMME CONTROL UNIT designed for the automatic control of sample changing equipment and print-out apparatus. Provides two presettable coincidence settings and has many uses in auto-machine control etc.

* Decatronics — a word not yet in the dictionary, perhaps, but "coined" to designate that class of pulse counting and timing techniques developed around the decade counter tube.

Labgear Ltd.

LABGEAR

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53P. 4000 Pneumatic Controller . . . this outstanding controller is extremely versatile. It is suitable for field mounting, case mounting, or can be plugged in on F.P. Miniature Recorders.

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- **CONSTRUCTION:** Toroidally wound auto-transformers, with tracks formed on one face of the windings.
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- **INSULATION:** Specially processed plastic mouldings ensure minimum shrinkage due to heat and continuous use, and prevent any possibility of the turns slackening.
- **WINDING:** Of high conductivity copper, insulated with a synthetic enamel of the polyvinal acetal-phenal formaldehyde resin type, giving good space factor, exceptionally high abrasion resistance and prolonged heating resistance.
- **FRAME:** Of die cast aluminium, incorporating long spindle bearings and mounting feet to ensure accuracy and rigidity of the mechanism in relation to the fixing holes.
- **BRUSHES:** The brushes are of a special carbon for its contact resistance characteristics, shaped to give minimum loss, maximum strength and longest life.

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BERCO

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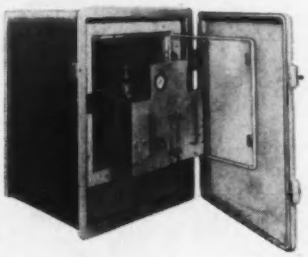
Process Analyser



The Pye Process Analyser is an industrial version of the well-known Pye Argon Chromatograph. By utilising an argon ionisation detector instead of a katharometer or thermistors, it achieves an outstanding performance with high sensitivity and exceptional stability. Its comparatively simple and robust design results in reliability, ease of operation and low overall cost.

The instrument draws a sample from the process stream, analyses it and presents the results on a recorder. A versatile control system selects and attenuates a number of individual peaks or gives a complete chromatogram.

The equipment, which is suitable for use in hazardous locations, is completely flexible in application. Facilities which may be supplied for individual installations include dual column analysis, multi-stream analysis, column switching, flow programming and others.

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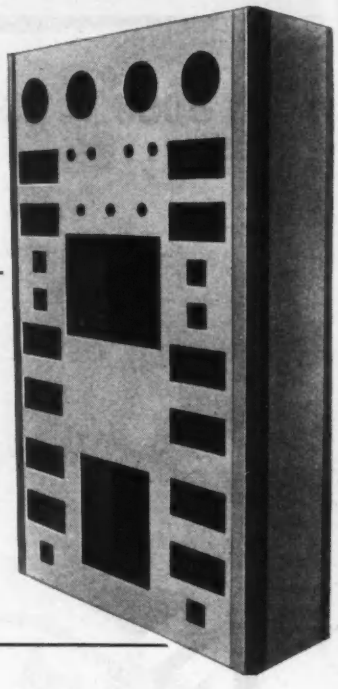
Datum INDUSTRIAL CUBICLES

TYPE **CP**

* **Heavy-duty cubicles suitable for electrical and industrial instrumentation.**
* **Full-width front plates for mounting indicating and recording instruments. Standard widths: 2′ 0″, 2′ 6″, 3′ 0″, 3′ 6″, 4′ 0″ and 4′ 6″.**
* **Complete rear access by means of lift-off panel, fitted C/P handle.**
* **Clear space for underfloor cabling and ducting.**

A Typical Control Panel... One of a range which can be supplied with apertures to your specific requirements. Standard Finishes are Light Grey 631 and Dark Grey 632 (BS 381C) but special colours are available to special order.



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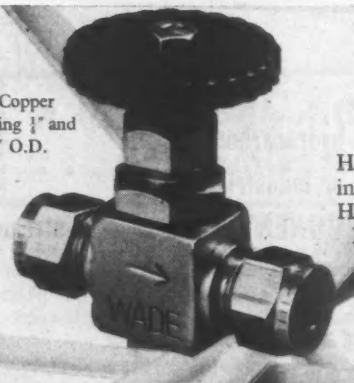
Join up with WADE

For Copper Tubing ¼″ and 5/16″ O.D.



Here is a good looking Medium Pressure Valve, made in high quality brass, with a Plastic Handwheel. It can be used for Copper, Nylon or Plastic Tubing. For Nylon, replace the Copper Compression Ring with the "N" Ferrule. For Plastic Tubing, these Valves are supplied with the Patent Wade "P" Joint, now in universal use.

For Nylon Tubing (with "N" ferrule)
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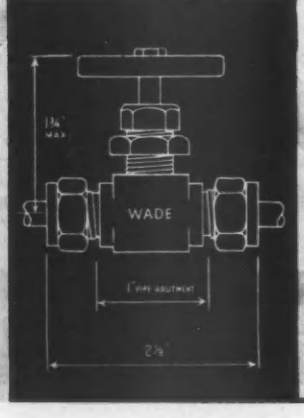
¼″ „ x 5/32″ „
5/16″ O.D. x ¼″ „
5/16″ „ x 3/16″ „



For Plastic Tubing
¼″ O.D. x 5/32″ I.D. and
5/16″ O.D. x 3/16″ I.D.

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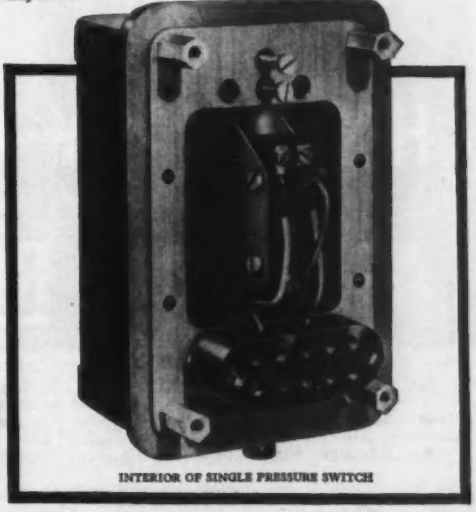
There is a range of Firth Cleveland lamp annunciators to keep an eye on things for you. These are designed for alarm and advisory functions wherever visual signals are required. Where you need the additional protection of an audible signal, we can arrange a bell, hooter or siren to be connected in parallel. A muting switch allows you to silence the signal once your attention has been attracted, and when conditions return to normal there is an automatic reminder for you to reset it. We have designed the case so that you can mount it to suit yourself—semi-flush or projecting from the panel. You can use these annunciators in conjunction with the Firth Cleveland capsule operated pressure switches for liquid level alarm indication.

Single switch units are available for high or low alarm, and double switch units where dual protection is required.



INTERIOR OF SINGLE PRESSURE SWITCH

The range of Firth Cleveland industrial instruments also includes Hydrostatic tank contents gauges and pressure relief valves all of which are complementary to each other. We shall be happy to send you full details.

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CRC310

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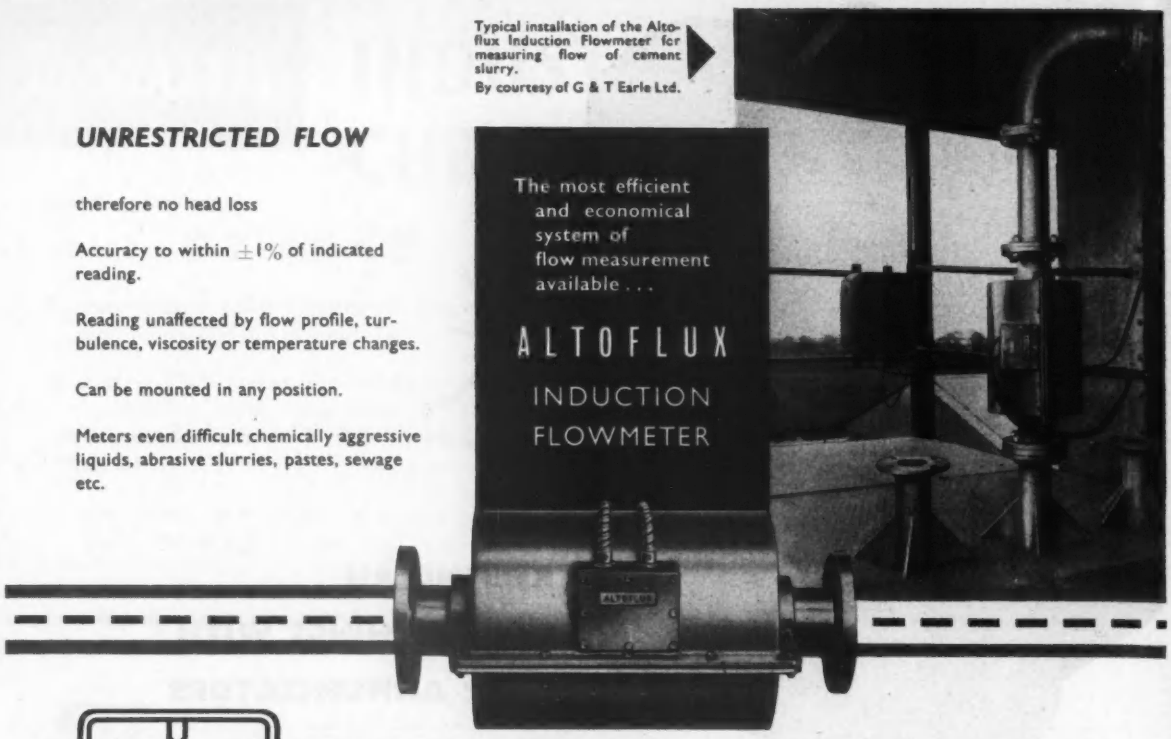
Typical installation of the Altoflux Induction Flowmeter for measuring flow of cement slurry.
By courtesy of G & T Earle Ltd.



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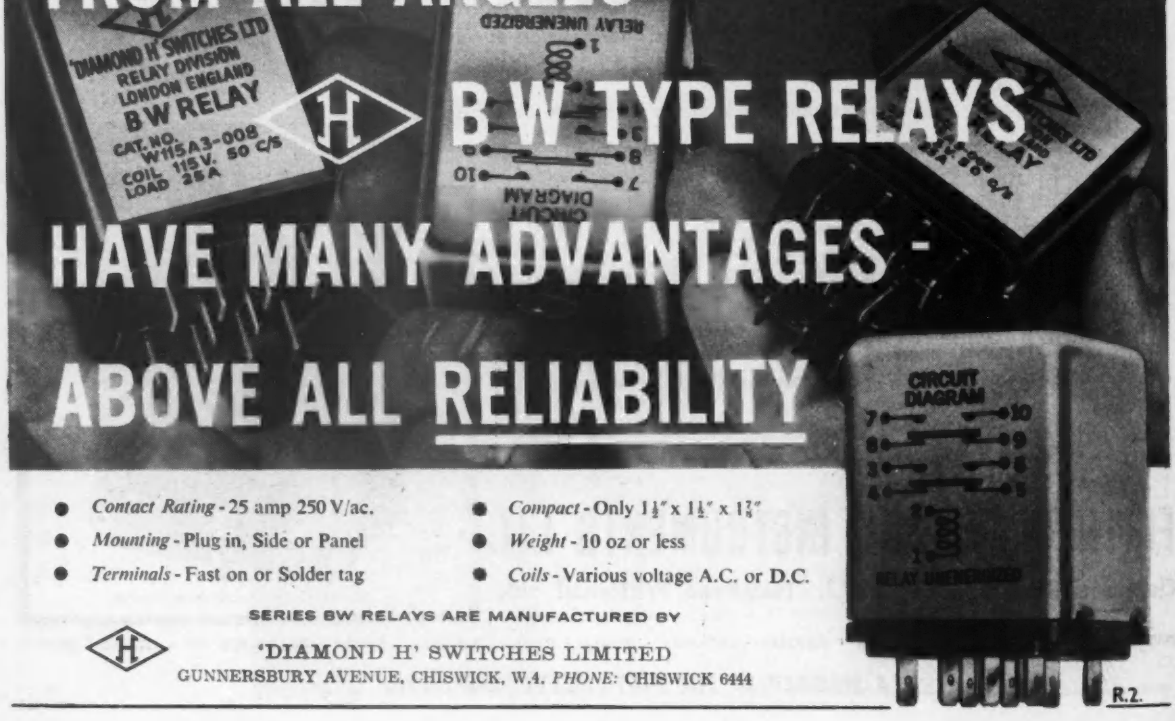

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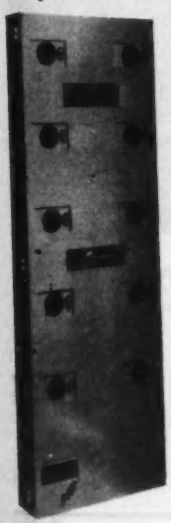

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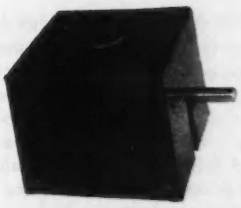

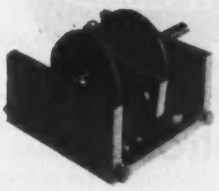

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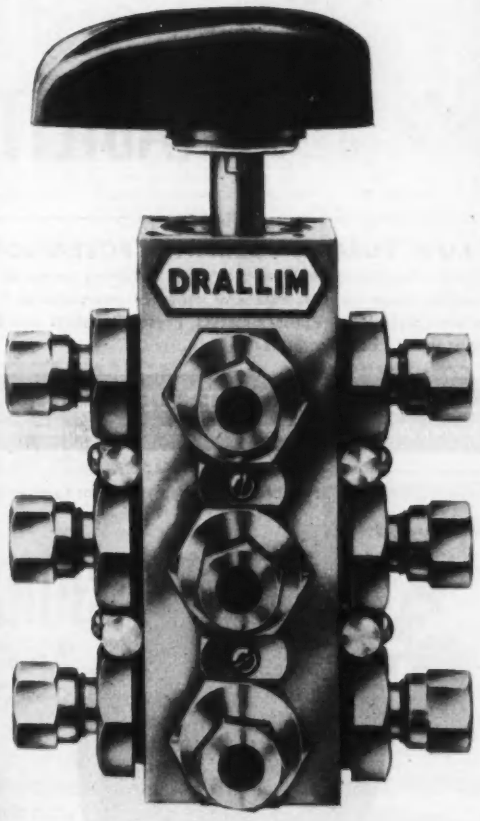

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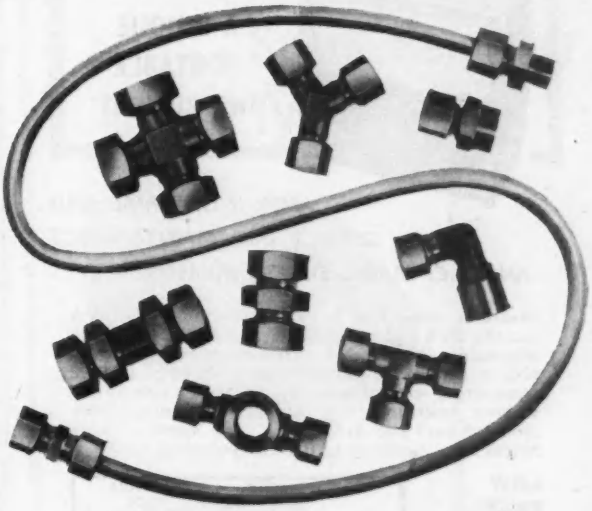

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MODEL 5000

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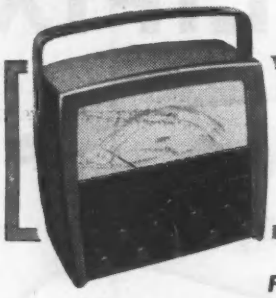

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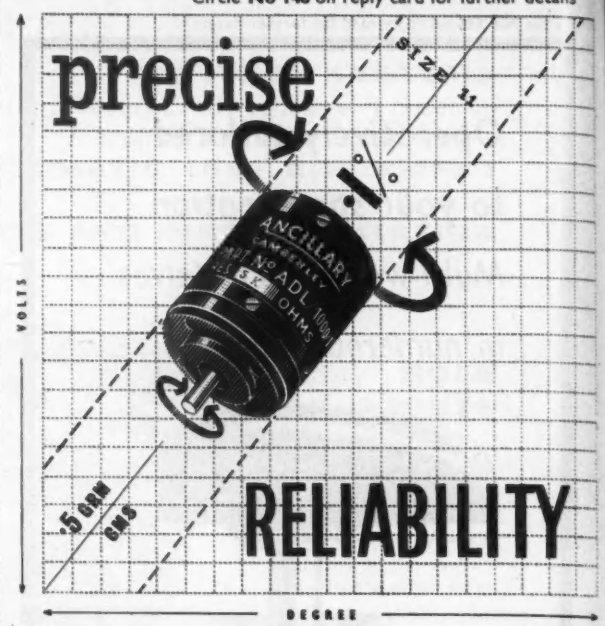

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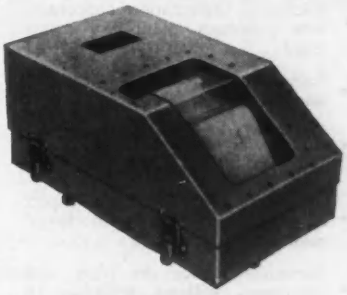

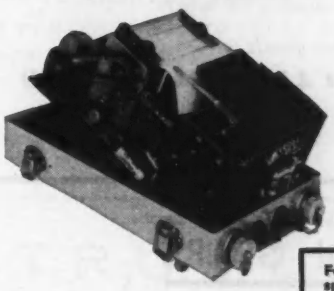

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Supply — 12 Volt, D.C.

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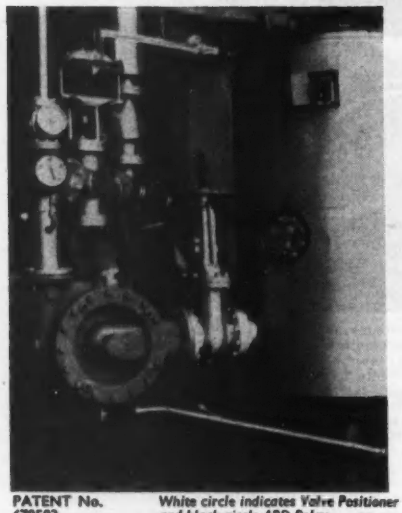

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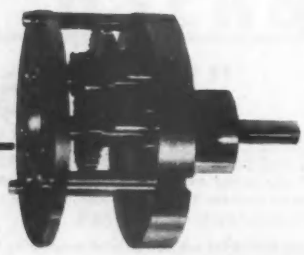

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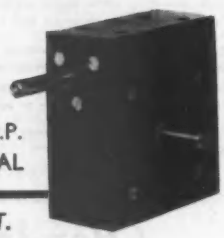

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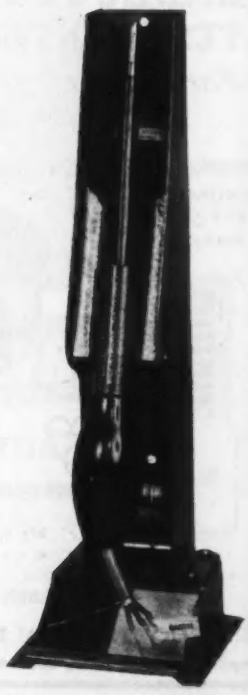

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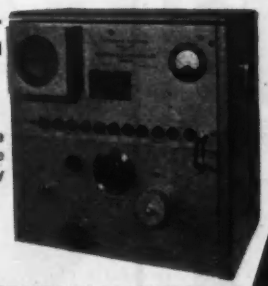

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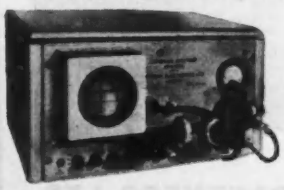

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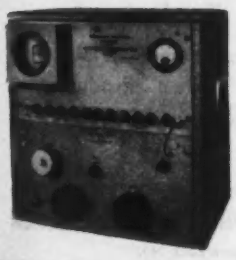
SPECTRUM ANALYSERS



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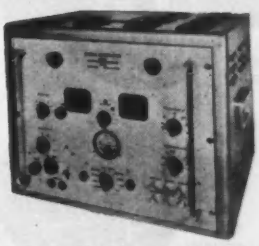

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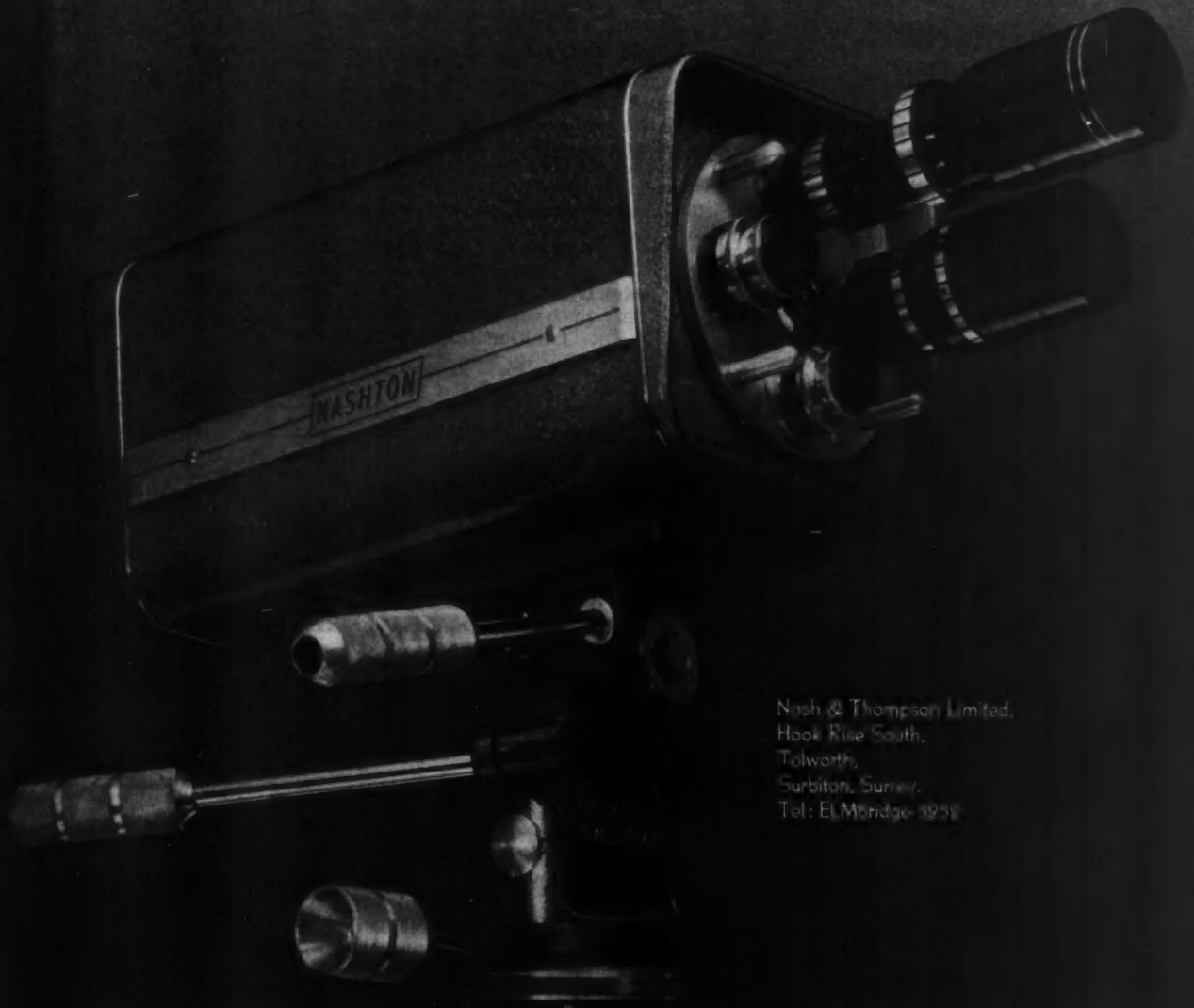

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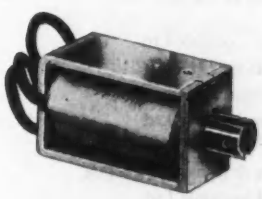

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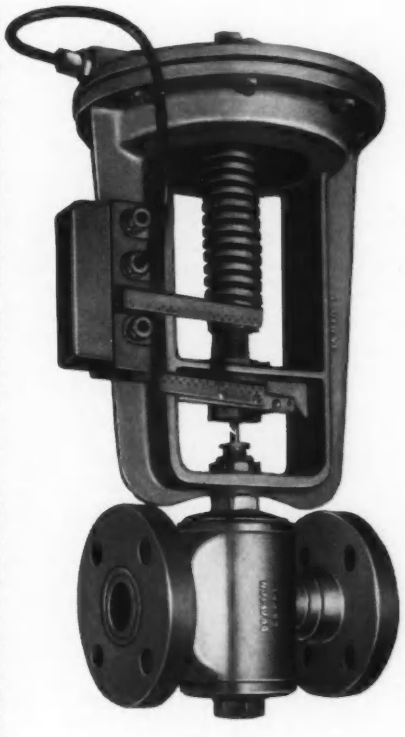

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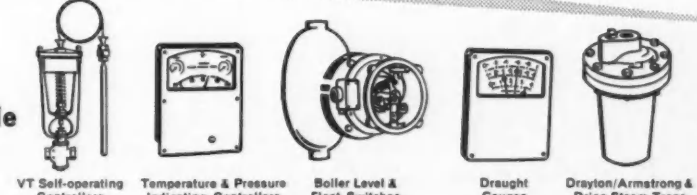

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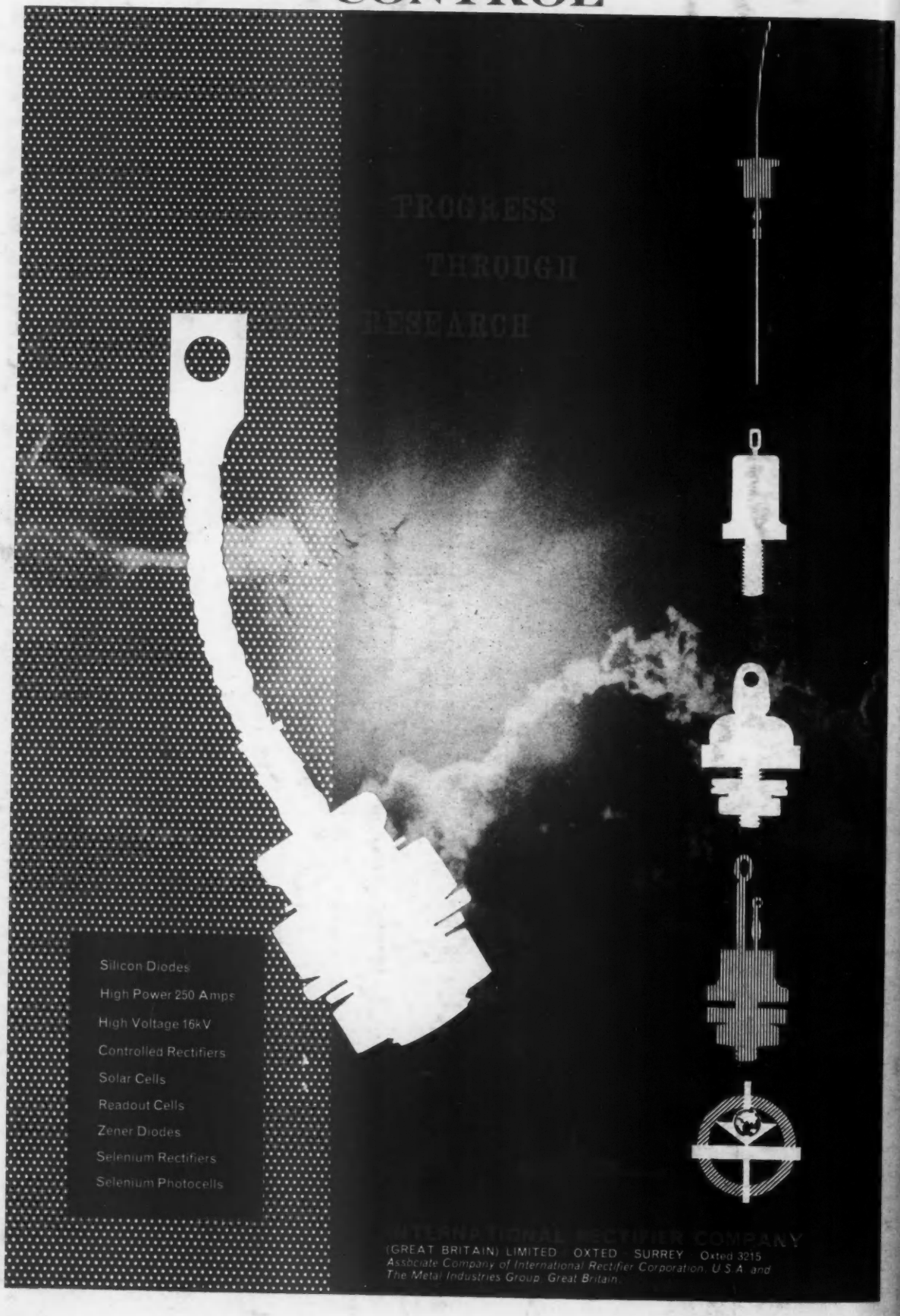

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